

Microwaves & RF

THE HIGH SPEED ELECTRONICS GROUP

News

Surveying the latest power dividers/combiners

Design Feature

Use an ESD-rugged device for automotive LNAs

Product Technology

Instrument analyzes RF signal sources

Software Speeds Complex IC Design

ETOOTH RECEIVER FRONT END (BiCMOS)

SRAM CELL (CMOS)

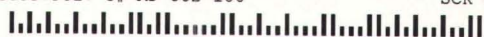
MIXER (SiGe)

ANSOFT

FREQUENCY DIVID

CIRCUIT DESIGN
CIRCUIT/SYSTEM CO-DESIGN
ON-CHIP INTERCONNECT DESIGN
AND POST-Layout VERIFICATION

#BXNPGNX *****AUTO**ALL FOR ADC 530
#533579017 5# RF 002 100 SKC 360



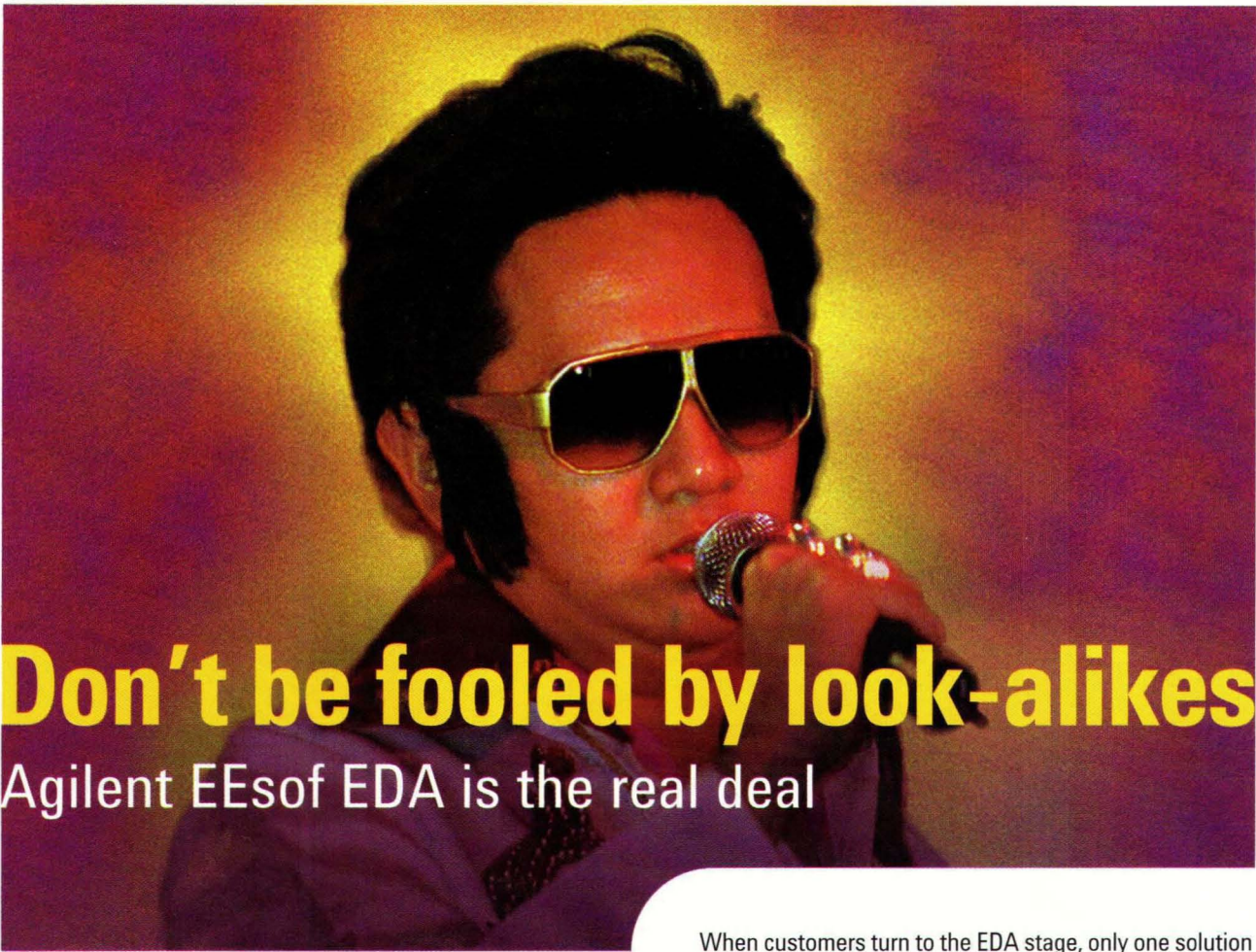
JOE LORITZ, ENGINEER
GBPPR
424 WILSON AVE
GREEN BAY

WI 54303-4115

**Amplifiers &
Oscillators
Issue**



WHAT'S NEXXT?



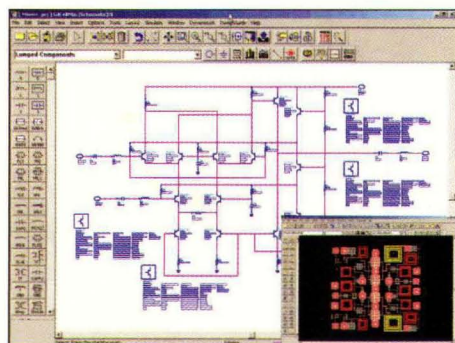
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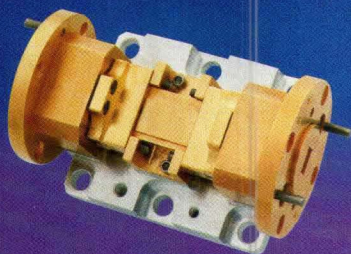


Agilent Technologies

dreams made real

MILLIMETER WAVE COMPONENTS

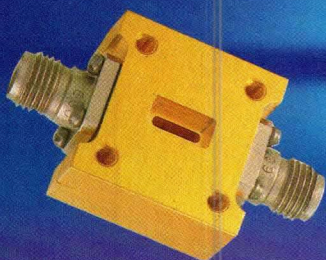
AMPLIFIERS • MIXERS • MULTIPLIERS



AMPLIFIERS

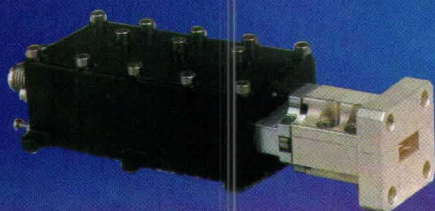
Model Number	Frequency (GHz)	Gain (dB, Min.)	Gain Flatness (±dB, Max.)	Noise Figure (dB, Max.)	In/Out VSWR (Max.)	Output Power at 1dB Comp. (dBm, Typ.)
JSW4-18002600-20-5A	18-26	34	1.5	2.0	2.0:1/2.0:1	5
JSW4-26004000-28-5A	26-40	25	2.5	2.8	2.2:1/2.0:1	5
JSW4-18004000-35-5A	18-40	21	2.5	3.5	2.5:1/2.5:1	5
JSW4-30005000-45-5A	30-50	21	2.5	4.5	2.5:1/2.5:1	5
JSW4-40006000-55-0A	40-60	16	2.5	5.5	2.5:1/2.5:1	0

Higher output power options available



MIXER/CONVERTER PRODUCTS

Model Number	Frequency (GHz)			Conversion Gain/Loss (dB, Typ.)	Noise Figure (dB, Typ.)	Image Rejection (dB, Typ.)	LO-RF Isolation (dB, Typ.)
	RF	LO	IF				
LNB-1826-30	18-26	Internal	2-10	42	2.5	20	45
LNB-2640-40	26-40	Internal	2-16	42	3.5	20	45
ARE3436LC1	34-36	15.5-16.5	2.7-3.3	25	4	20	60
SBW3337LG2	33-37	33-37	DC-4	-7.5	8	N/A	25
TB0440LW1	4-40	4-42	.5-20	-10	10.5	N/A	20
DB0440LW1	4-40	4-40	DC-2	-9	9.5	N/A	25
SBE0440LW1	4-40	2-20	DC-1.5	-10	10.5	N/A	20



MULTIPLIERS

Model Number	Frequency (GHz)		Input Level (dBm, Min.)	Output Power (dBm, Min.)	Fundamental Feed Through Level (dBc, Min.)	DC current @+15VDC (mA, Nom.)
	Input	Output				
MAX2M260400	13-20	26-40	10	10	18	160
MAX2M200380	10-19	20-38	10	10	18	200
MAX2M300500	15-25	30-50	10	10	18	160
MAX4M400480	10-12	40-48	10	10	18	250
MAX3M300300	10	30	10	10	60	160
MAX2M360500	18-25	36-50	10	10	18	160
MAX2M200400	10-20	20-40	10	10	18	160
TD0040LA2	2-20	4-40	10	-3	30	N/A

Higher output power options available

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Model	Freq. Range GHz	Gain dB min	Flatness +/-dB Max	1 dB Comp. pt. dBm min	N/F Max	3rd Order ICP typ	VSWR In/Out Max
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LNA's

JCA12-3001	1.0-2.0	40	1.0	10	0.8	20	2.0
JCA24-3002	2.0-4.0	40	1.0	10	1.0	20	2.0
JCA48-4001	4.0-8.0	42	1.5	15	1.0	25	2.0
JCA812-5001	8.0-12.0	45	1.5	10	1.5	20	2.0
JCA1218-5002	12.0-18.0	48	1.5	10	1.5	20	2.0

Ultra Low Noise Amplifiers

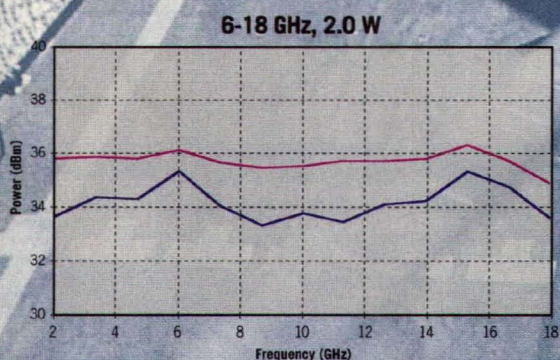
JCA45-306	4.5-4.8	40	0.5	10	0.5	20	2.0
JCA45-305	4.4-5.1	30	0.5	10	0.7	20	2.0
JCA56-309	5.4-5.9	30	0.5	10	0.7	20	2.0
JCA78-306	7.25-7.75	30	0.5	10	0.7	20	2.0
JCA12-3040	1.2-1.6	30	0.5	10	0.7	20	2.0

Broadband Power Amplifiers

JCA618-4001	6.0-18.0	40	1.5	33	3.0	40	2.0
JCA218-3002	2.0-18.0	34	2.0	27	4.0	33	2.0
JCA218-4002	2.0-18.0	44	2.5	27	4.0	32	2.0
JCA218-5002	2.0-18.0	54	2.5	27	4.0	32	2.0
JCA218-3001	2.0-18.0	30	2.0	25	4.0	30	2.0

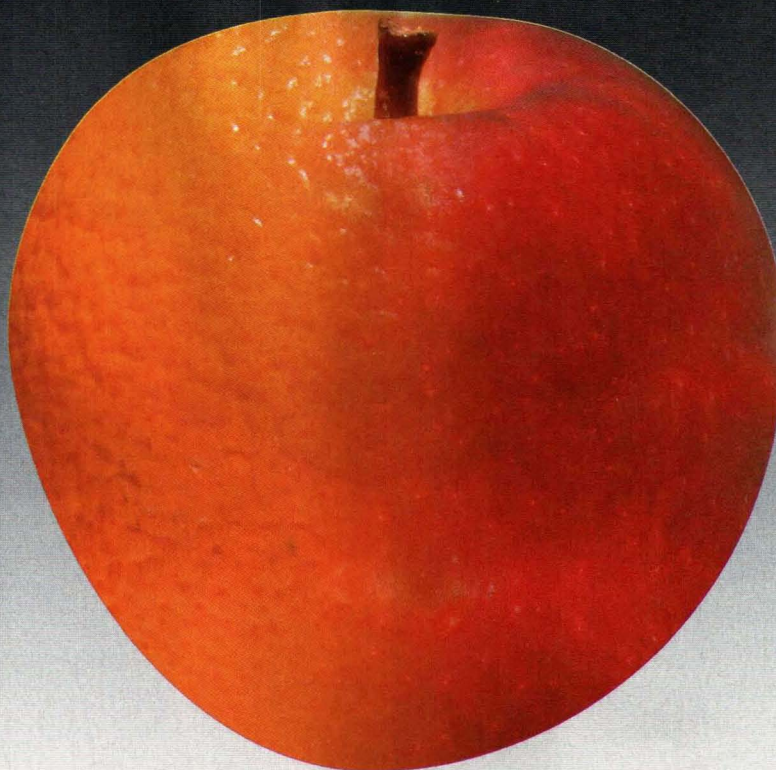
Low Phase Noise Amplifiers

Carrier Offset	C, X-Band (-dBc/Hz)	Ku-Band (-dBc/Hz)
100 Hz	135	125
1.0 kHz	145	142
10 kHz	153	150
100 kHz	158	152



- Amplifiers
- Digital Optics
- High-Power Laser Diodes

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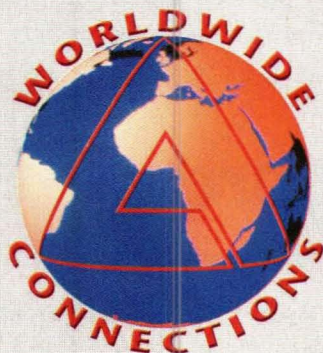
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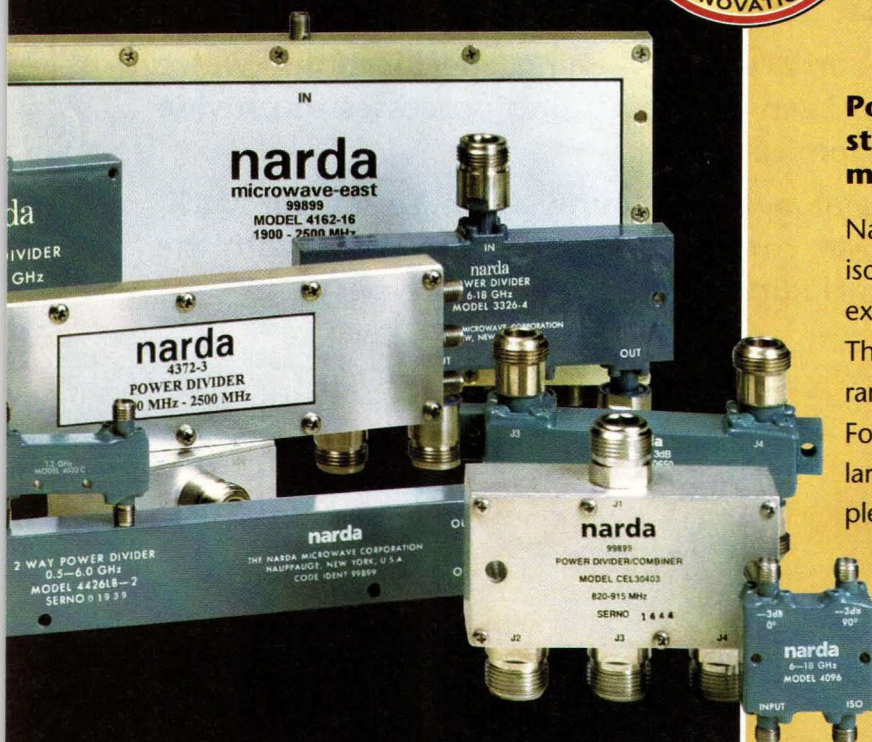
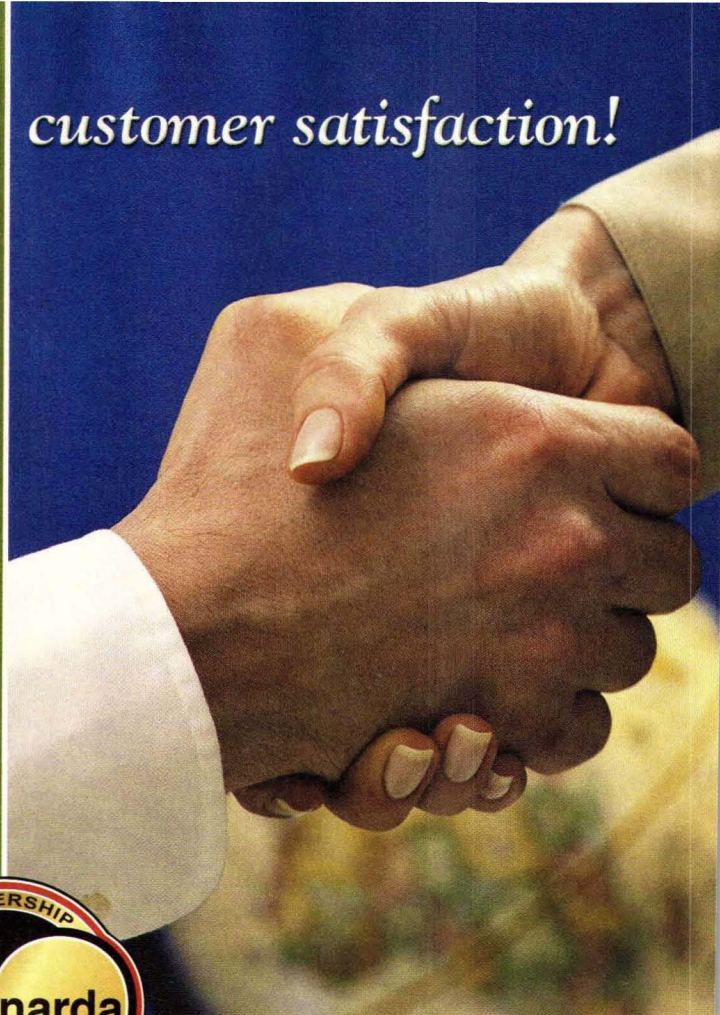

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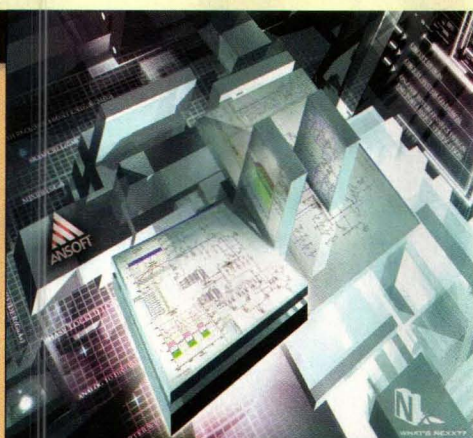
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COVER STORY

92 Software Speeds Complex IC Design

This new simulation and analysis tool provides a high degree of accuracy and transistor-level detail while performing computations at five to ten times the speed of existing CAE tools.



News

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Choosing To Combine Or Divide Power

These essential components are available from a large number of suppliers in a variety of forms and package styles, including near chip-size drop-in power dividers/combiners.

Design

57

ESD-Hardened Device Fuels UHF Amplifiers

This rugged bipolar transistor has been designed to withstand high levels of ESD making it well suited for UHF automotive electronics applications.

67

Applying S-Parameters To Amplifier Design

This opening installment of an eight-part design series explains the concept of S-parameters and how they can be used to create basic transistor bias circuitry.

80

Tracking Generators Enhance Spectrum Analysis

The combination of a tracking generator and a spectrum analyzer enables swept scalar frequency-response measurements of active and passive networks.

Product Technology

97

Instrument Evaluates Oscillator Performance

This compact, multifunction instrument evaluates oscillator and source noise, transients, tuning linearity, and output power from 10 MHz to 7 GHz.

100

Fixtures Accurately Test High-Power Transistors

With interchangeable components to handle a wide range of devices, these fixtures address the unique needs of characterizing high-power transistors.

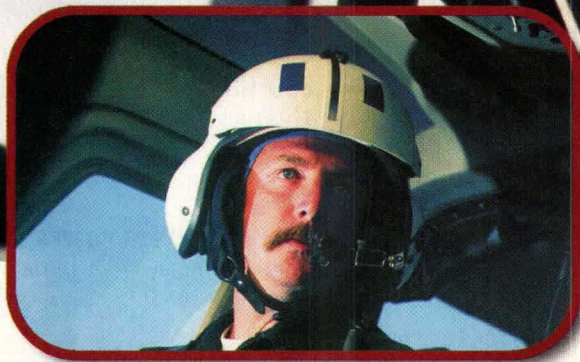
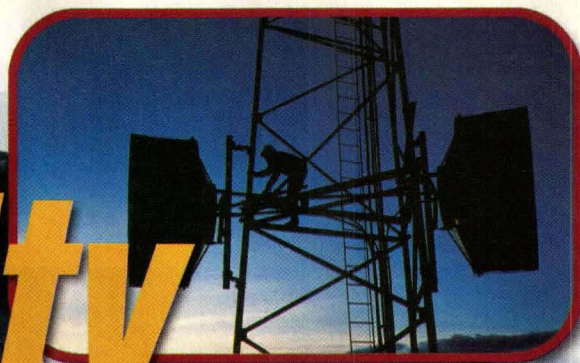
102

MEMS Switches Run For 100 Billion Cycles

These rugged MEMS switches offer low insertion loss, high isolation, and high linearity for a variety of commercial and military applications needing high reliability with low current consumption.



quality



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equipment, your customers
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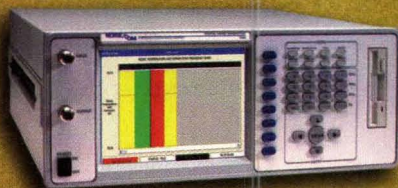
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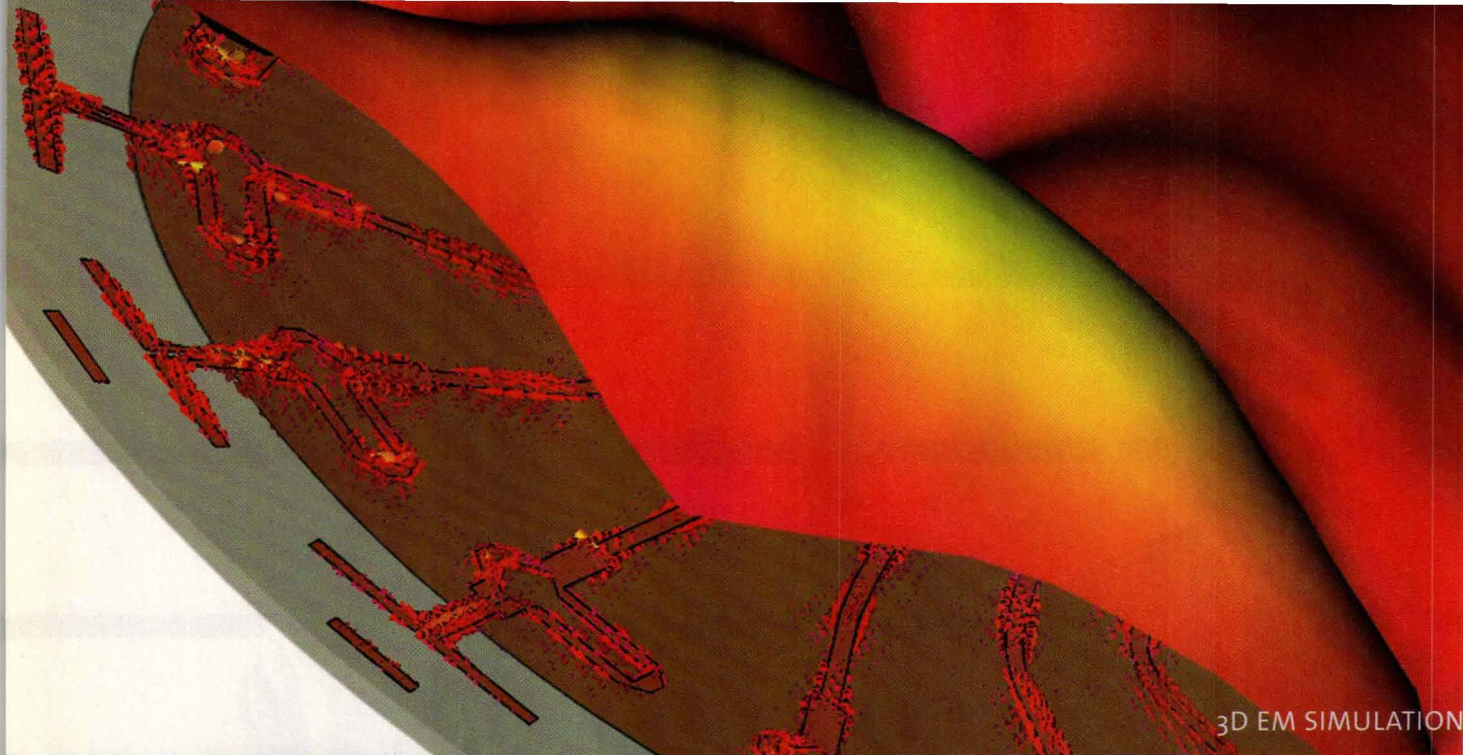
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- ▶ Resistors: Resistance, RF Power, VSWR, Shunt Capacitance

Reliability:

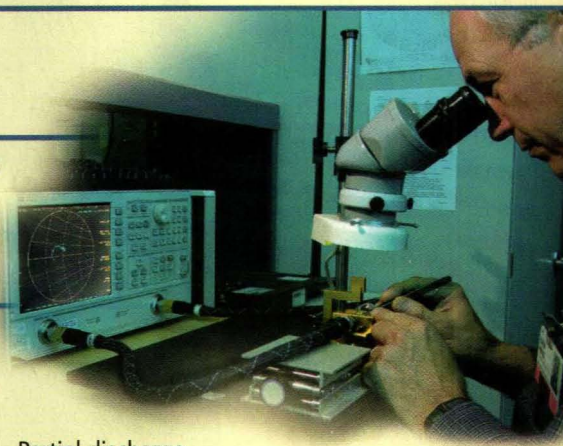
- ▶ ATC's tradition is to achieve the highest reliability levels for all product lines.

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- ▶ Full Burn In and Life Test Capability
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- ▶ Thermal Characterization
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- ▶ Specialized test fixtures designed in house to support a full range of customer requirements



Frequency Range: 2 MHz to 1 GHz

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4.7 μ H - 1000 μ H, 0.16 - 1.9 Amps
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DS3316 Shielded Series

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0.33 μ H - 3.3 μ H, 6.4 - 16 Amps
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D01608/3316 Series

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38 values (3 each) Kit C105 \$90

DS5022 Shielded Series

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13 values (3 each) Kit C117 \$60

D05022 Series

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17 values (3 each) Kit C111 \$60

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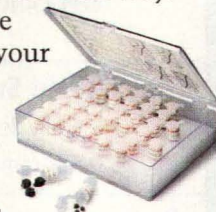
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MODEL NUMBER	CENTER FREQUENCY (MHz)	FREQUENCY SPAN (MHz)	DYNAMIC RANGE (dB)	GAIN FLATNESS (\pm dB)	AGC GAIN VARIATION (dB)
HAGC-70-21-4-15-I/O*	21.4	15	70	0.15	0.5
HAGC-70-30-20-I/O*	30	20	70	0.25	0.5
HAGC-70-70-40-I/O*	70	40	70	0.30	0.5
HAGC-70-140-80-I/O*	140	80	70	0.60	0.6
HAGC-60-160-80-I/O*	160	80	60	0.60	0.6

*Input(I)/output(O) impedance can be 50 (I or O = 5) or 75 (I or O = 7) ohms independent of each other

- Low Power Consumption
- Models Are Available With Various Dynamic Ranges
- Very Low Intermodulation Distortion (65 dB typical across dynamic range)

HIGH PERFORMANCE PULSED IF ANALOG AGC AMPLIFIERS



MODEL NUMBER	CENTER FREQUENCY (MHz)	FREQUENCY SPAN (MHz)	DYNAMIC RANGE (dB)	AGC RESPONSE TIME (Pulse Bursts)	AGC TRACKING ACCURACY* Δ PIN \leq 65 dB		
					250 ns PULSE (dB Max.)	500 ns PULSE (dB Max.)	2 μ s PULSE (dB Max.)
GAGC-65-21.4-6	21.4	6	65	25	$\leq \pm 2.5$	≤ 2	≤ 2
GAGC-65-30-10	30	10	65	25	$\leq \pm 2.5$	≤ 2	≤ 2
GAGC-65-70-24	70	24	65	25	$\leq \pm 2.5$	≤ 2	≤ 2
GAGC-65-140-40	140	40	65	25	$\leq \pm 2.5$	≤ 2	≤ 2
GAGC-65-160-60	160	60	65	25	$\leq \pm 2.5$	≤ 2	≤ 2

*Settled response over multiple pulse bursts. Minimum operating pulse width (PW) is 250 ns. Minimum PRF is 160 Hz.

- Digital/Analog Processing Feedback Circuitry

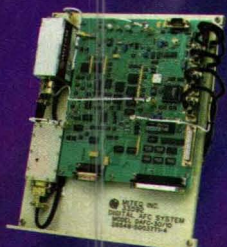
HIGH PERFORMANCE PULSED IF ANALOG AFC AMPLIFIERS



MODEL NUMBER	CENTER FREQUENCY (MHz)	PEAK-TO-PEAK BANDWIDTH (MHz)	TRANSFER SLOPE (V/MHz)	PULSE WIDTH (μ s)	DROOP RATE μ V/MS
AFCP-5-21.4-6	21.4	6	0.8	0.5	75
AFCP-8-30-10	30	10	0.5	0.4	75
AFCP-16-60-20	60	20	0.25	0.2	60
AFCP-20-70-24	70	24	0.20	0.18	60
AFCP-28-140-40	140	40	0.15	0.125	60
AFCP-30-160-60	160	60	0.125	0.100	60

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DAFC-21/6	21.4	3	1.5	350	150	100	15
DAFC-30/10	30	5	2	250	125	75	10
DAFC-35/14	35	7	2.5	250	125	75	10
DAFC-60/20	60	10	4	200	100	75	10
DAFC-160/40	160	20	10	175	100	75	10

*Settled response over multiple pulse bursts. Minimum operating pulse width (PW) is 250 ns. Minimum PRF is 160 Hz.

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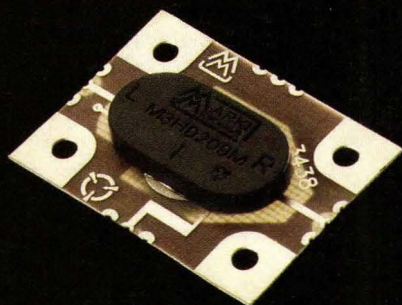


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Design Feature Corrections

►► THE DESIGN FEATURE article that appeared on pages 88 to 98 of the May 2004 issue of *Microwaves & RF* ("Estimate Multiple Carrier Difference" by Howard Hausman) contained at least two errors that are described below.

The first error:

Fig. 1 on p. 88 plots Pout, third-order dBm versus Pin dBm. The light blue curve (line) labeled "Third-order dBm" clearly has a slope of +2 as shown. The third-order intermodulation curve, being a cubic product, should have a slope of +3. The error may be that the ordinate was labeled dBm and should be dBc.

The second error:

On p. 93 at the bottom of the first column, the author

incorrectly states, "For system bandwidths less than an octave, even-order intermodulation products are out of band."

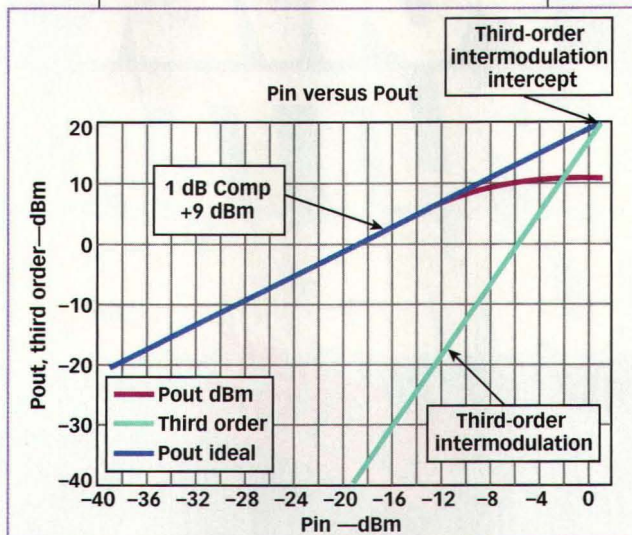
Here is a simple counter example of an even-order product that is in-band. For simplicity, consider the less-than-octave band from 10 to 17 GHz.

The signals at $F_1 = 10$ GHz and $F_2 = 16$ GHz are in band and their fourth (even) order product $2F_2 - 2F_1 = 12$ GHz is clearly in band.

Andrew Zeger

Howard Hausman responds: Mr. Zeger, thank you for the corrections to my article. Your observations were valid in both areas.

As per your first observation, The article should have read "second-order intermodulation products" instead of "even-order intermodulation products." With that said, it should be noted that odd-order intercept points are usually a lower level than the surrounding even-order intercept points and, therefore, more of a concern to the systems designer. Typically, the second-order (continued on page 40)



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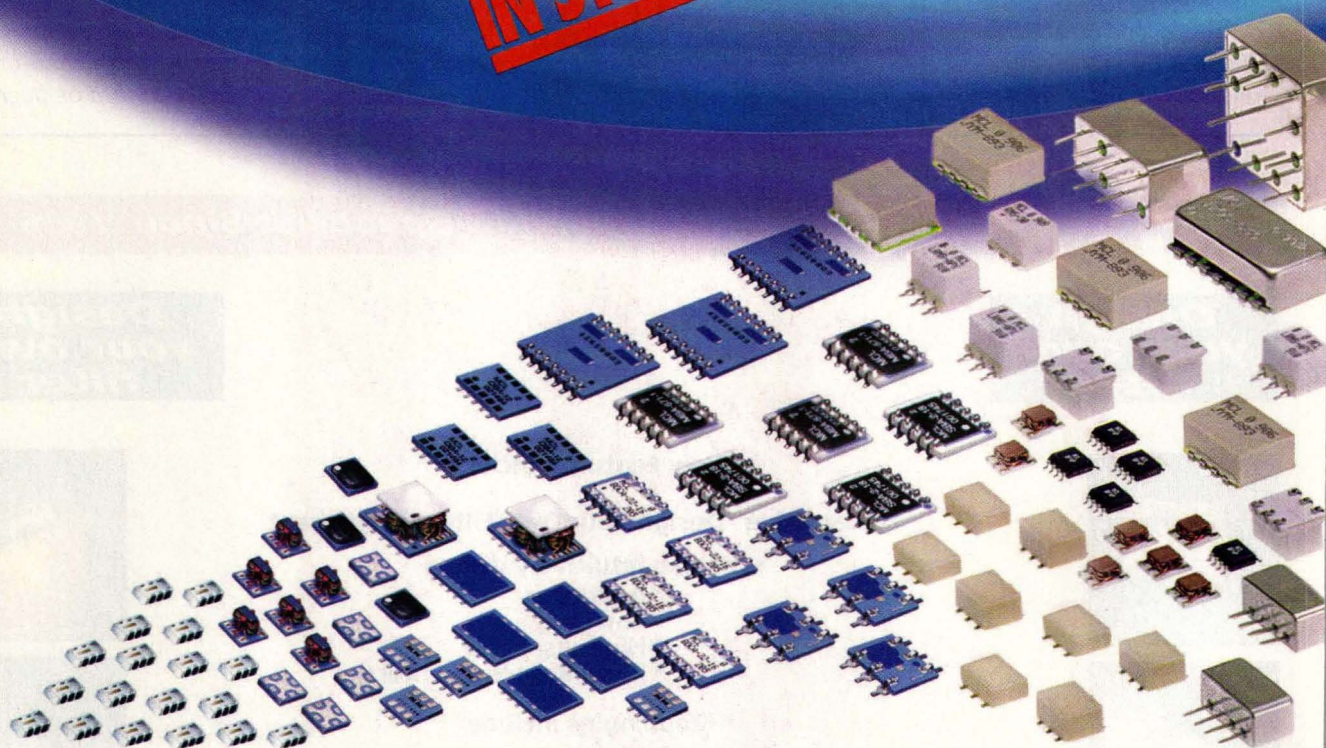
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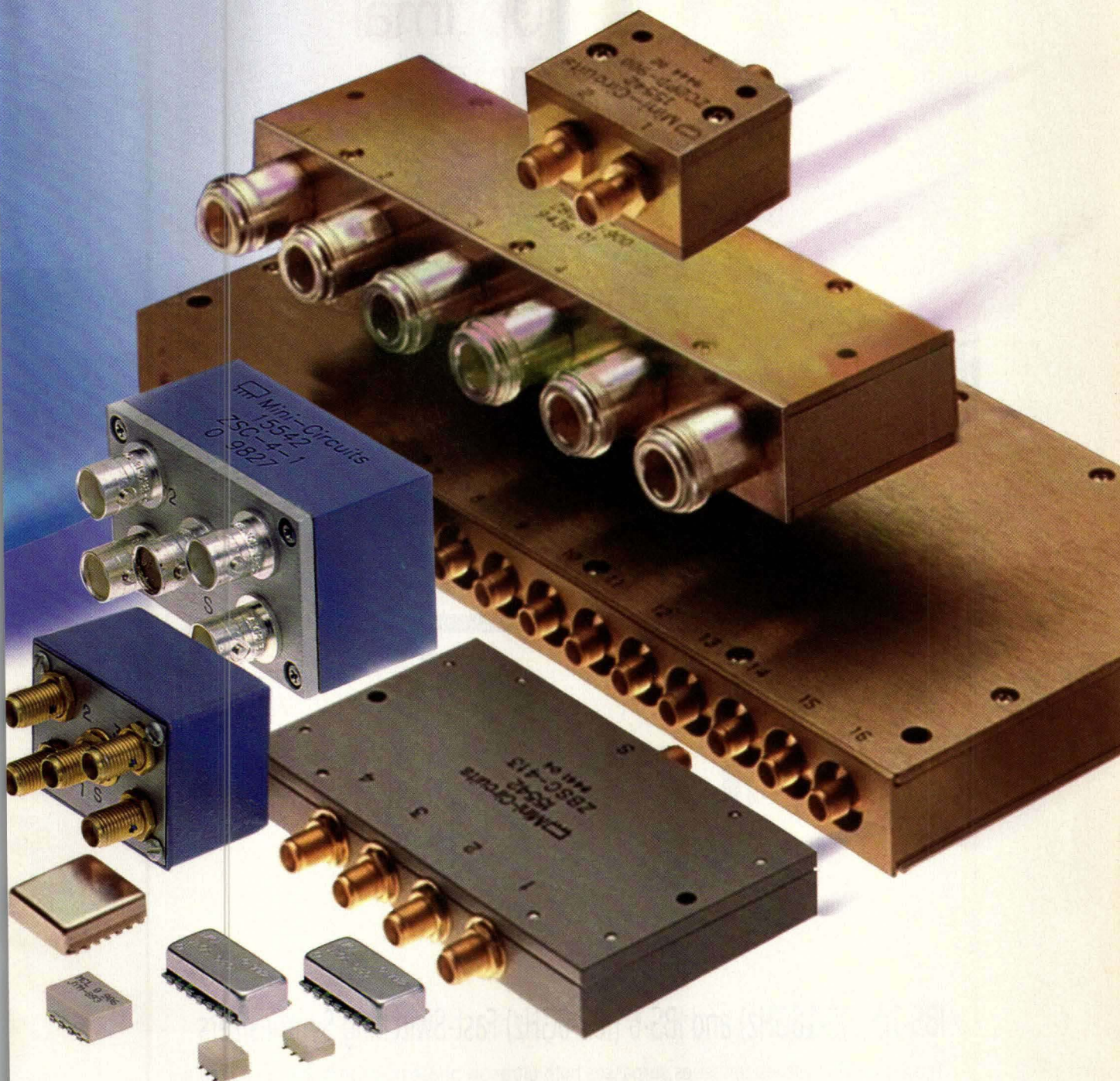
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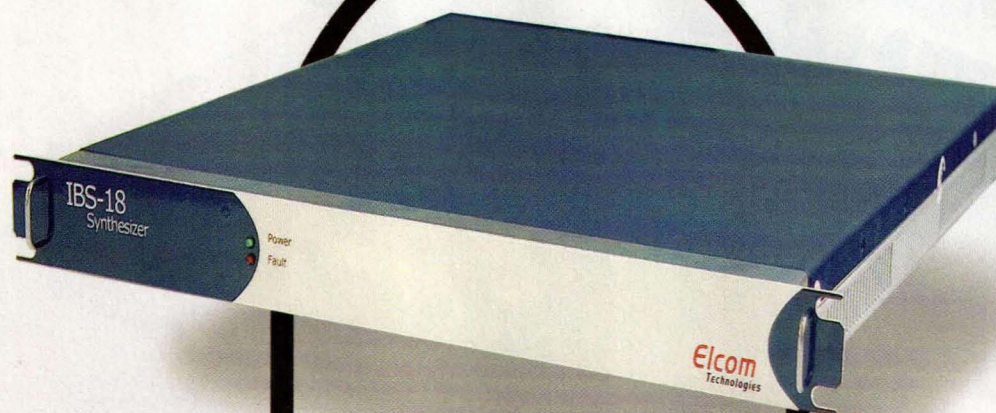
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Noise Floor	-153	-153	-153	-150

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Understanding SpecsmanSHIP

POWER DIVIDERS/COMBINERS are considered "essential" components by most amplifier designers. Now available at RF and microwave frequencies in a wide range of packages from roughly 100 suppliers (not to mention distributors), these versatile components allow the combining of multiple power transistors in a high-power-amplifier (HPA), for example, or the splitting of signals two, four, or almost as many ways as desired. A Special Report beginning on page 33 details some of the things to look for when selecting a power combiner/divider.

In the midst of poring over hundreds of data sheets of research on power dividers (tirelessly collected and captured from websites by Editorial Assistant Dawn Prior), it became apparent that specifications are not always what they seem. The two obvious examples of this are two of the power divider/combiner "quality" specifications: amplitude unbalance (or balance or tracking) and phase unbalance. While almost every manufacturer standardizes the way they present their own data, comparing data between different manufacturers can sometimes be a challenge. For these two specifications, for instance, many manufacturers choose to present their performance levels in terms of a deviation, such as ± 0.3 dB for amplitude unbalance and ± 6 deg. for phase unbalance. But just as many manufacturers present these same two specifications as the total range of unbalance, namely, 0.6 dB for amplitude unbalance and 12 deg. for phase unbalance. And in some unfortunate cases, suppliers list what appears like it should have been a deviation, such as ± 0.5 dB for amplitude unbalance, as simply 0.5 dB.

Some manufacturers are to be applauded for their efforts to provide as much data (for a comparison) as possible. Mini-Circuits (Brooklyn, NY, www.minicircuits.com), for example, is one of the few power divider/combiner suppliers that include a set of S-parameter data for their components. This data shows values that are considerably higher (certainly not an advantage) than those of competitors, because the data also include division losses (along with the expected insertion loss). While making their products appear to have worse performance (if not properly compared) than a competitor, these data are useful to designers who must consider all losses in a microwave link budget, for example.

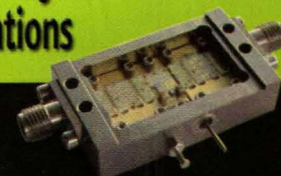
Until the industry agrees on a standard format to present data, power divider/combiner specifications (including CW and peak power) must be interpreted before they can be meaningfully compared. But while there is room for interpretation, there is room for specsmanSHIP and unfair comparisons.



Some manufacturers are to be applauded for their efforts to provide as much data (for a comparison) as possible.

Jack Browne
Publisher/Editor

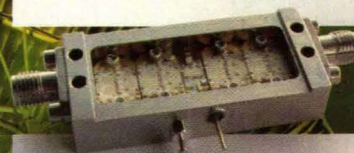
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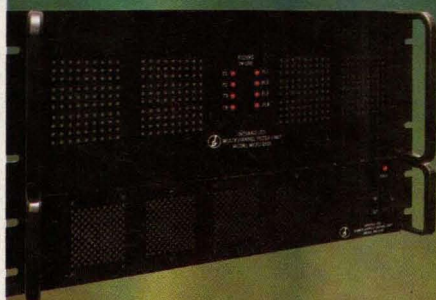


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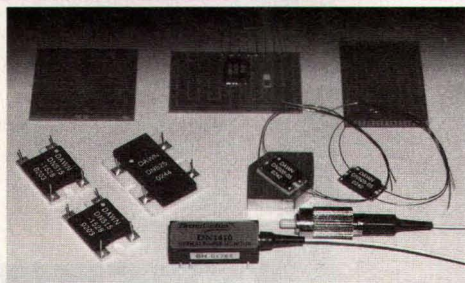


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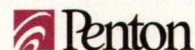
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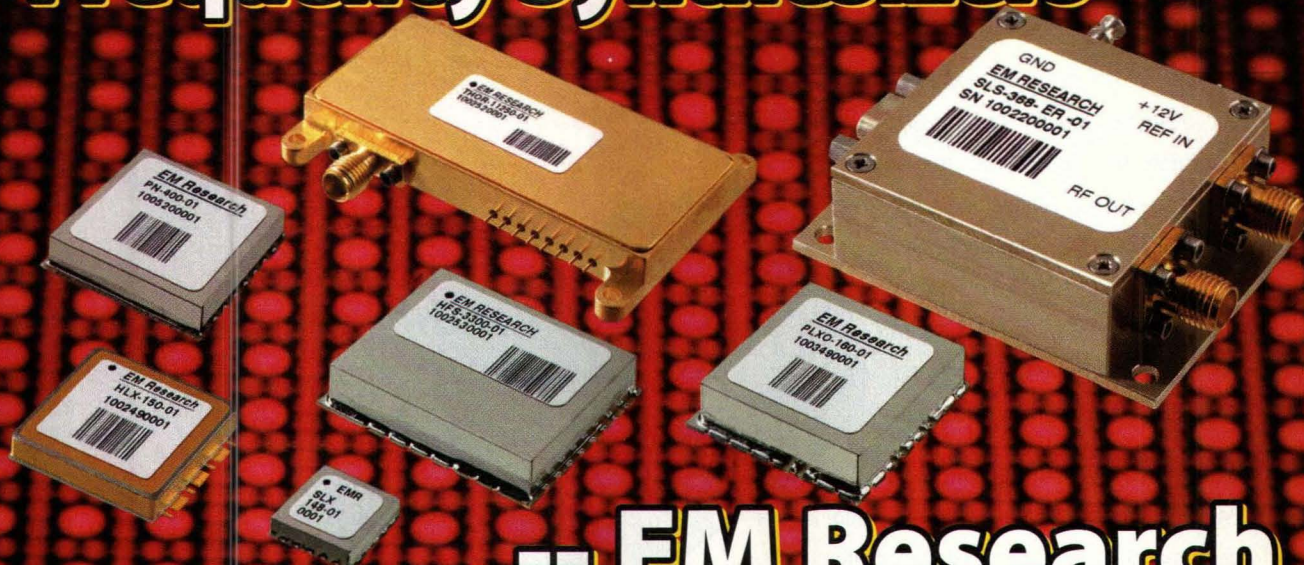
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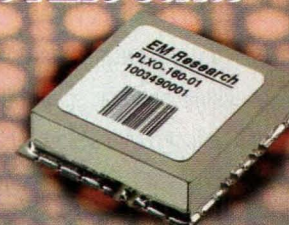
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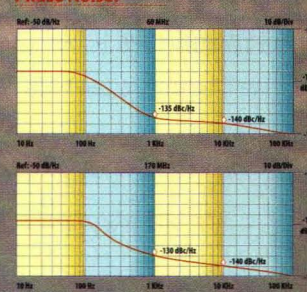
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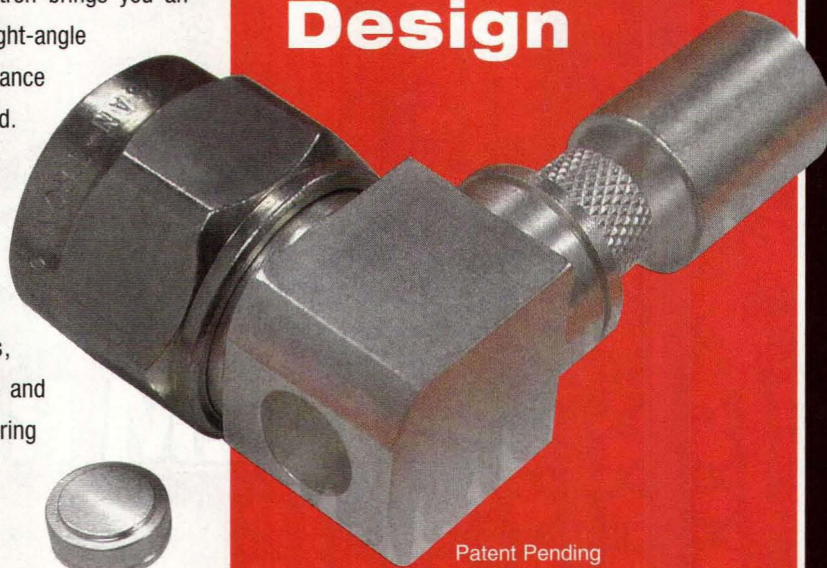


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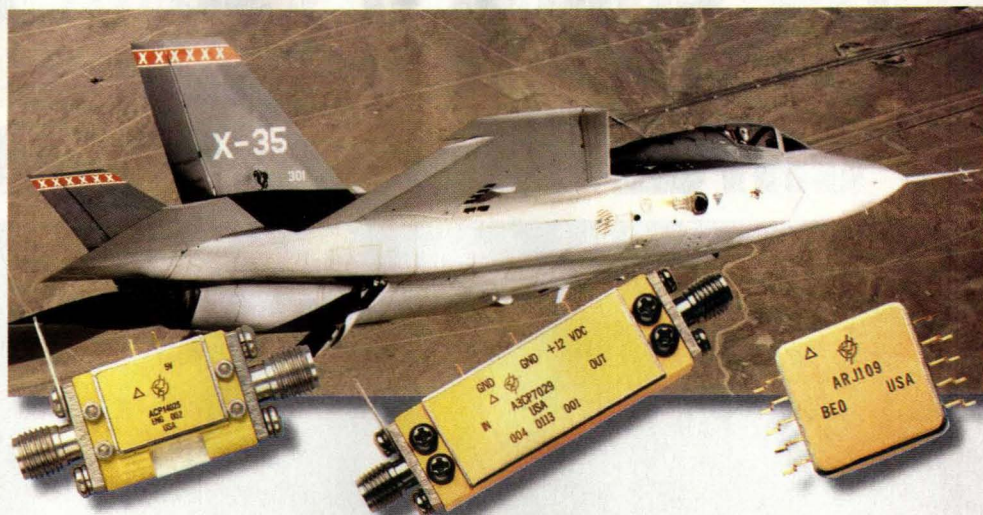
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AP448	10-400	10.5	4.3	24.8	42/53	15	110
AP1309	10-1300	12.5	2.5	23.0	36/49	15	100
AP2009	10-2000	11.0	3.5	28.0	40/50	15	188
AP3509	100-3500	8.5	5.5	27.0	38/48	15	190
A2CP5008	2000-5000	12.0	3.0	24.5	35/50	12	250
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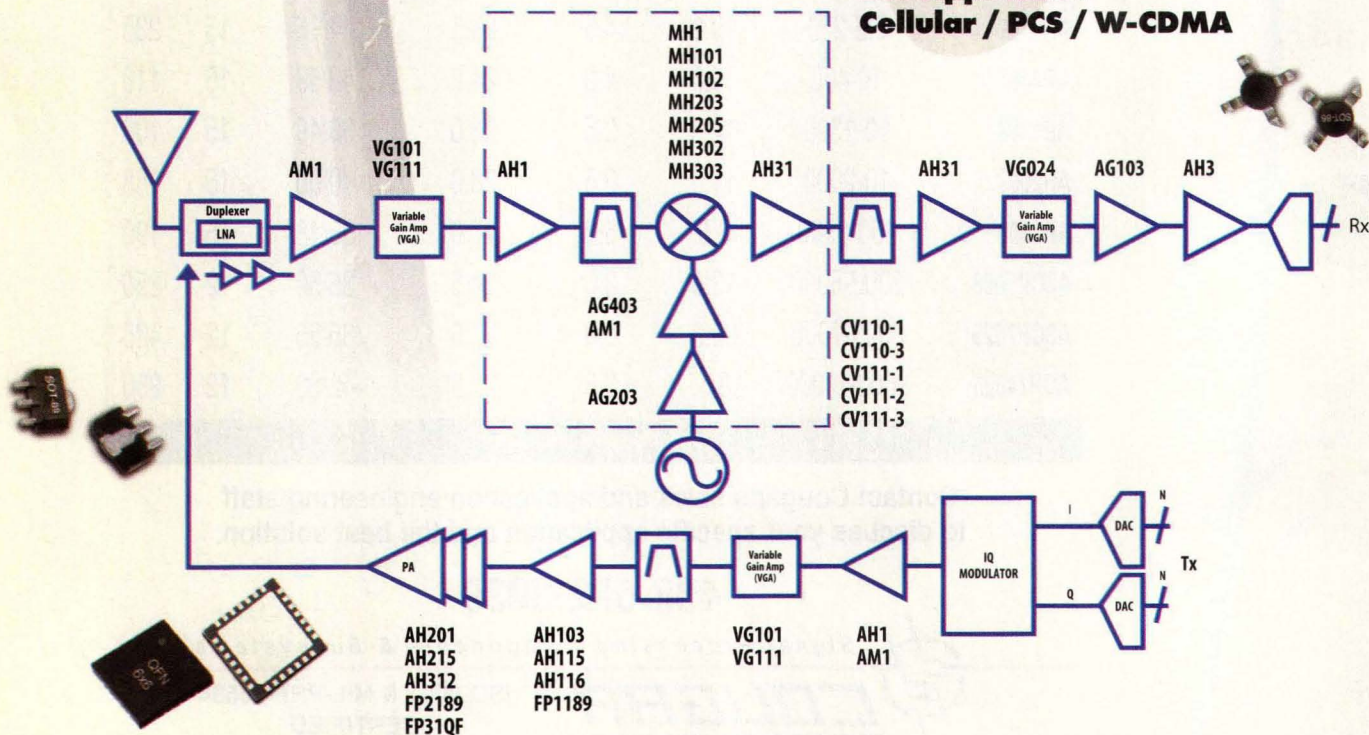
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News items from the communications arena.

US MEMS Demand Is Slated To Reach \$3.3 Billion In 2008

CLEVELAND, OH—The US market for micro-electromechanical systems (MEMS) is projected to increase better than 19 percent per year through 2008 to \$3.3 billion (see table). Fueling gains will be further recovery in technology sector business fundamentals, advances in MEMS design and fabrication techniques, and an expanding scope of applications for MEMS-based solutions. MEMS products holding especially good prospects include optical switches for both telecom carrier and internal corporate networks; RF switches and relays for wireless phones and related devices; and advanced actuators such as biochips for complex biomedical testing and analysis. These and other trends are presented in *MEMS Micro-Electromechanical Systems*, a new study from The Freedonia Group, Inc., a Cleveland-based industrial research firm.

The three best established products within the MEMS market—airbag accelerometers, ink-jet printer heads, and blood-pressure monitoring sensors—are becoming mature, and will register respectable although by no means stellar growth over the next several years. As a result, the strongest gains will occur in new products and emerging applications.

Among end users, the most rapid growth will occur in the telecommunications sector, as MEMS-based optical switching finally begins to gain some commercial traction along with recovery in sector capital spending, and as the market for MEMS-based RF switches and relays continues to develop.

US MEMS market (Millions of dollars)

ITEM	%ANNUAL GROWTH				
	1998	2003	2008	03/98	08/03
MEMS market by application	795	1370	3300	11.5	19.2
Automotive	295	435	875	8.1	15.0
Information processing	260	390	600	8.4	9.0
Biomedical	100	215	525	16.5	19.5
Telecommunications	20	60	450	24.6	49.6
Consumer	35	75	275	16.5	29.7
Other	85	195	575	18.1	24.1

©2003 by The Freedonia Group, Inc.

Laird Technologies' Chris Alderson Is Awarded An MBE

ST. LOUIS, MO—Laird Technologies Japan employee, Chris Alderson, has been awarded an MBE (Member of the order of the British Empire) in Queen Elizabeth's Birthday Honors list. The award, for "services to British industry," comes as reward for Alderson's efforts in establishing and developing a successful manufacturing operation in Japan.

In 1999, Alderson was recruited by RFI Shielding Ltd. to set up and run a form-in-place gasket facility, to dispense electrically conductive seals on to small electronic devices, such as mobile phones and PDAs. Alderson developed business relationships with many of the major Japanese electronics giants, including Sony, Panasonic, Sanyo, Kenwood, and Toshiba.

Nippon RFI Shielding KK, of which Alderson was president, became part of Laird Technologies in December 2003, and now employs 30 people at its Yokohama base. Alderson has now taken on a business-development role for the group, covering the whole of the Asia Pacific region.

Philip Mizen, general manager of Laird Technologies UK, states, "Chris is a remarkable young man, extremely gifted and tenacious. This is a just recognition of Chris' skill in successfully introducing a new technology into a notoriously difficult market for foreign companies to break into."

Alderson, 31, is a fluent Japanese speaker and keen follower of Japanese culture. He has been living and working in Japan for the past eight years.

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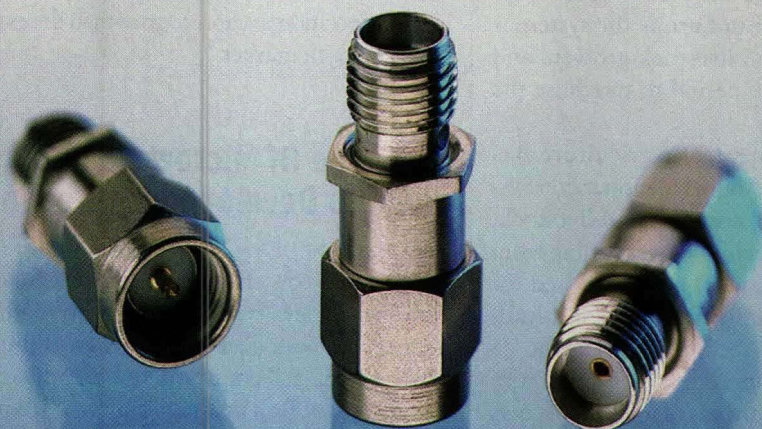
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RFID Will Find A Major Niche As A Livestock Tracker

OYSTER BAY, NY—"One RFID market that's gaining a lot of momentum at present is animal tracking," says Sara Shah, an analyst at ABI Research. "Because of the BSE ("mad cow disease") outbreak in Europe, an RFID initiative to track animals was begun there."

When the first cases of BSE were discovered in North America, investigations into their source revealed the lack of any standardized national tracking system for the movements of live cattle, or beef products.

Other countries already have such systems in place. In Australia, a major beef supplier, a mandatory RFID-based National Livestock Identification Scheme has been in place since 2002. Shah says that in Europe the system is still being set up, and livestock growers and vendors have a grace period to purchase the technology.

The US Department of Agriculture has launched a National Animal Identification System (NAIS) to cover most forms of livestock. While a number of technologies ranging from retinal scans to genetic ID are shortlisted for use in such a system, RFID tagging is a leading contender, and is recommended by the US Animal Identification Plan's Beef and Dairy Working Groups. With tens of millions of cows in the US market at any given time, but only an estimated 2 percent now RFID-tagged, this represents a very sizeable growth potential for the RFID market.

ABI Research's report, *RFID Readers: Analysis of Applications, Standards, and Global Markets*, focuses on these all-important links between external data and the internal company network. It examines the design and components of the several kinds of RFID readers, and their integration into a total system. An RFID technology summary details standards, frequencies, and applications.

RF Micro Devices Completes Acquisition of Silicon Wave

GREENSBORO, NC—RF Micro Devices, Inc., a provider of proprietary RF integrated circuits (RF ICs) for wireless-communications applications, announced that it has completed the acquisition of Silicon Wave, Inc., a privately held, San Diego-based supplier of highly inte-

grated Bluetooth solutions for wireless personal area networks (WPANs).

The acquisition of Silicon Wave expands RFMD's total addressable market and is expected to complement its leadership position in handsets. RFMD is currently ramping volume production of Silicon Wave's Bluetooth components for handsets manufactured by a tier-one handset maker. In addition to handsets, the company's Bluetooth products are in use supporting multiple applications, including headsets, printers, and PC peripherals.

Frank Morese, vice president of RFMD's wireless-connectivity business unit, comments, "We're excited to join forces with Silicon Wave to significantly enhance our Bluetooth product portfolio. We believe our combined strengths and unique technology place us in an extremely strong position to capture growth in the explosive Bluetooth market."

New Type Of Microwave Component Is Developed In Sweden

UPPSALA, SWEDEN—The research and development company Racomma has developed a completely new type of microwave component that is anticipated to be of great importance to the telecom and space industries, among others. By a new application of a "smart material," a type of component between traditional passive and active components has been created.

This new technology makes it possible to externally adjust or upgrade not only the software, but also the hardware in microwave circuits and systems. One conceivable application of this is the Earth-based adjustment of hardware in microwave circuits of satellites to compensate for the large temperature fluctuations in space, thereby achieving considerably better performance.

Microwave circuits consist of a metal layer with a specified geometry. Different geometries provide different performance. With this new technique, the geometry, and thereby the circuit's performance, can be changed. Simply put, this is made by a layer consisting of a metal hydride comprising a part of the circuit. By changing the voltage, the metal hydride can be made to switch between a conducting and an insulating state, and then remain in that selected state. The geometry can be changed in such a manner.

“One RFID market that's gaining a lot of momentum at present is animal tracking.”

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S5W2	S5W5	N5W5	5	±0.40
S6W2	S6W5	N6W5	6	±0.40
S7W2	S7W5	N7W5	7	±0.60
S8W2	S8W5	N8W5	8	±0.60
S9W2	S9W5	N9W5	9	±0.60
S10W2	S10W5	N10W5	10	±0.60
S12W2	S12W5	N12W5	12	±0.60
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AIT Wireless Acquires Licensing For New Antenna Technology

LAKELAND, FL—AIT Wireless, Inc., a distributor office telephone and network systems, has announced that a Letter of Intent has been signed to acquire licensing for the Advance Membrane Transducer Technology from Porrazzo Strategic Technologies through Good Works, Inc.

"This thin membrane transducer technology totally replaces traditional antenna technology; therefore, traditional 'Line of Sight' is not necessary. The potential to enhance the functionality of any electronic device that requires an antenna is profound, including wireless DSL, Point to Point, and Point to Multipoint. We are very excited to be a part of introducing this product through our product and distribution channels," explains Ernest Phillips, vice president of business development for AIT.

When asked how confident he was in its performance, Frank Estill, president of AIT, adds, "This technology has been developed and tested in the most rugged of field conditions. Both our armed forces and several unnamed government intelligence agencies have been utilizing this technology in areas of conflict for several years, working with the developers to refine its applications. This product will have broad market implications."

Kudos

PALO ALTO, CA—Agilent Technologies, Inc. announced that it has been recognized for its market leadership by Frost & Sullivan in three areas. Agilent was also named Frost & Sullivan's 2004 Preferred Test and Measurement Vendor of the Year.

Agilent also announced that it has shipped its 800th 93000 system-on-a-chip (SoC) Series tester. **SHERBROOKE, QUEBEC, CANADA**—C-MAC MicroTechnology has announced TS16949 Certification of C-MAC Microcircuits, Inc., its North American hybrid circuit manufacturing facility, located in Sherbrooke.

WEST PALM BEACH, FL—SV Microwave, Inc. is being presented with the Program Executive Office Integrated Warfare Systems (PEO IWS) Excellence Award (the highest US Navy award given to a civilian company), which recognizes top suppliers with exceptional performance in quality, delivery, affordability, and program management.

POCATELLO, ID—AMI Semiconductor has been named the ASIC/MMIC/FPGA Commodity Supplier of the Year 2004 by Rockwell Collins.

The Supplier of the Year award is an acknowledgement of significant contributions made during the year by suppliers and is based on delivery, cost of ownership, lead time, and customer metrics.

MYRTLE BEACH, SC—AVX Corp. has received recognition from Arrow Electronics, a firm involved in electronics distribution. For the second year in a row, AVX was recognized with the Supplier Excellence of PEMCO Products award. This award named AVX as the passive component supplier that exhibited the best supplier performance for the year 2003. **WAYNE, NJ**—ANADIGICS, Inc. has been granted patent 6,580,321 for a new active clamping circuit that protects GSM power amplifiers (PAs) from damage under extreme operating conditions. The new clamping circuit is simpler than previous designs and takes up less board real estate.

BURBANK, CA—Microfabrica, Inc. has now exceeded 100 US and foreign patents issued or pending.

The patents pertain to the company's EFAB[®] micro-manufacturing technology, which offers 3D flexibility, ease-of-use, and quick time-to-market in a wide array of applications from wireless electronics to industrial instrumentation.

The patents cover all aspects of EFAB technology, from the basic process to enhancements that make it suitable for certain product segments; pre and post processing steps (including packaging); and novel product design ideas. They also include the inventions of the founding team at the University of Southern California (USC), which are now exclusively licensed to and controlled by Microfabrica.

KOWLOON, HONG KONG—Enthone, Inc. has announced that Shenzhen Huamei Electroplating Technology Ltd. was voted as the "Best Brand" in a survey conducted by the Market Information Centre of People Daily (Beijing, China). Specifically, survey participants ranked Huamei Electroplating as having the best electroplating additives in what was the very first "Chinese National Survey on Product Quality and Customer Satisfaction—Corporate (branding)" conducted in mainland China.

PLAINVIEW, NY—Aeroflex, Inc. received this year's Frost & Sullivan Award for Growth Strategy Leadership at the 2004 Excellence in Industrial Technology Awards, which were held on May 19 in Miami, FL. **MRF**

"This product will have broad market implications."



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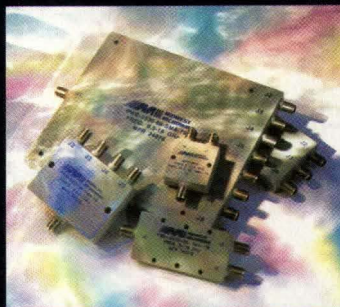
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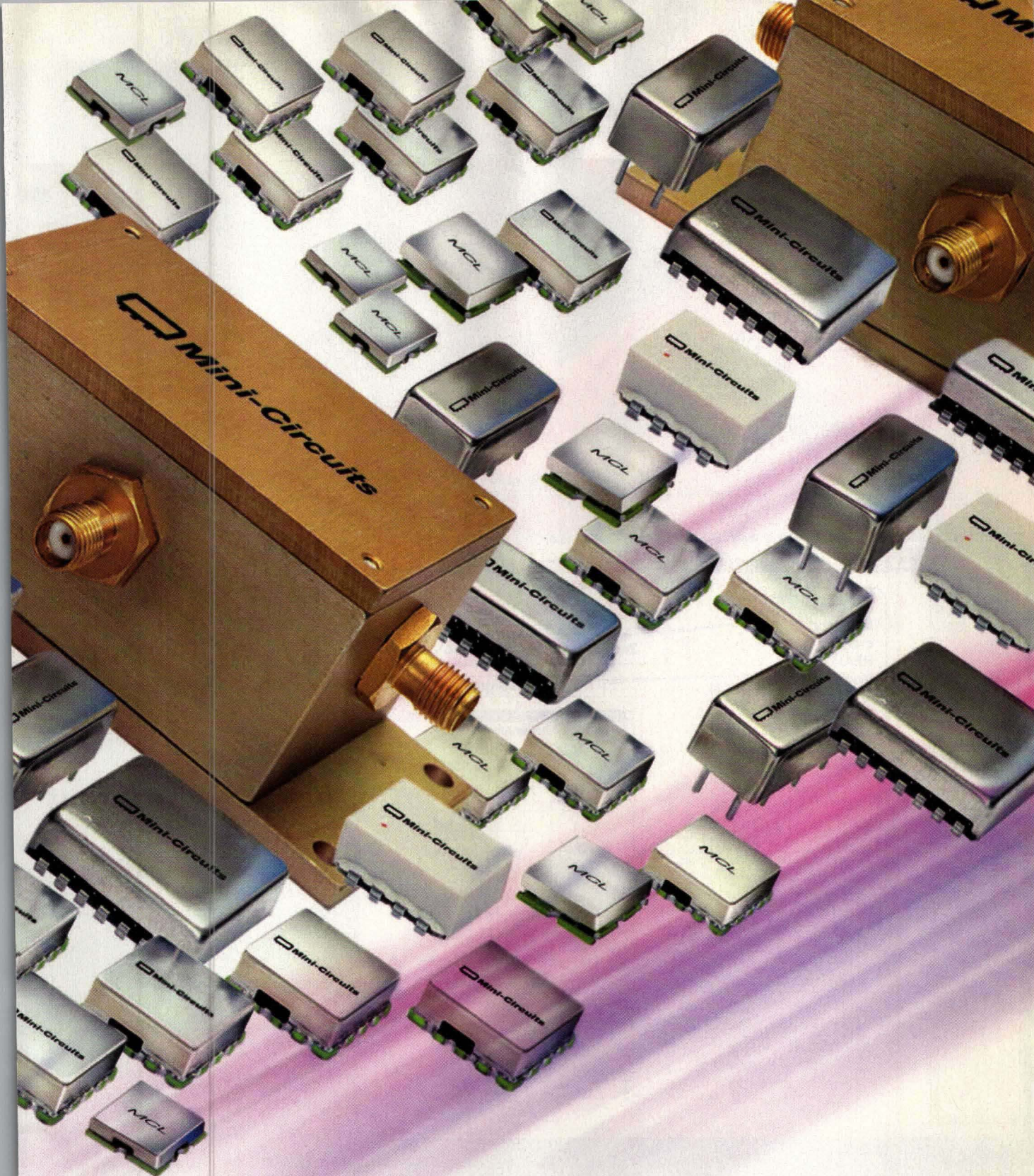
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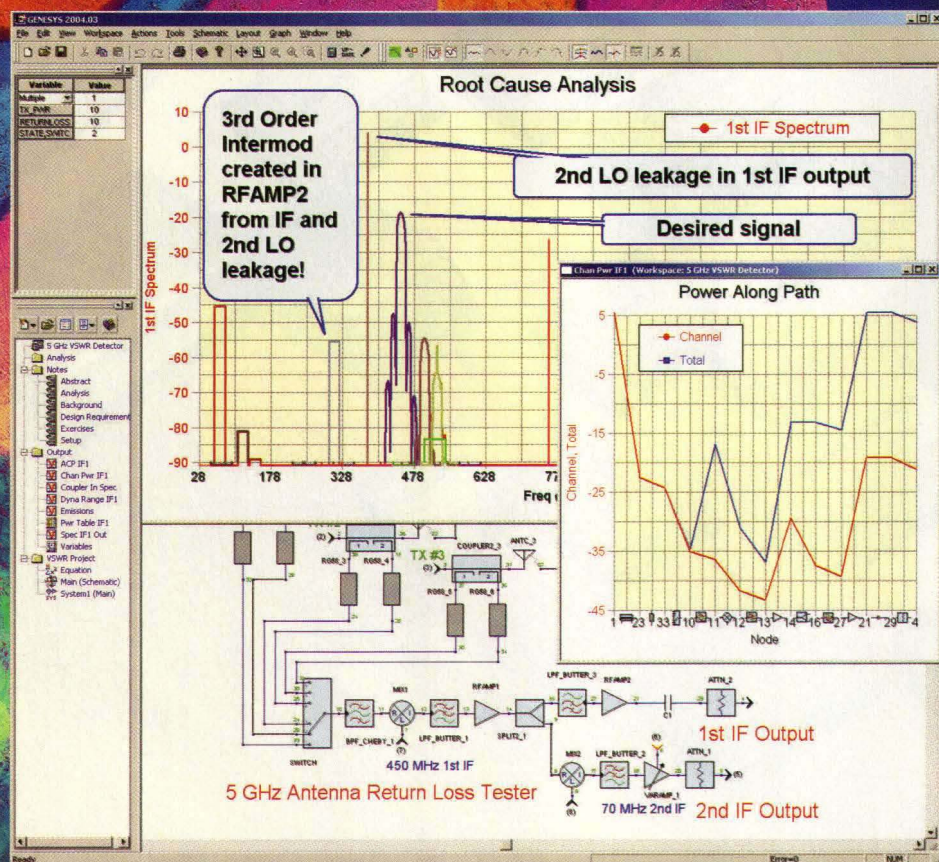
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Choosing To Combine Or Divide Power

These essential components are available from a large number of suppliers in a variety of forms and package styles, including near chip-size drop-in power dividers/combiners.

Power must often be combined from multiple transistors in an amplifier or antennas in a system, or divided among channels in a receiver. For that reason, the humble RF/microwave power dividers/combiners is among the most competitive product areas in this industry, with about 100 different suppliers. To make an educated decision when specifying a power divider/combiner, it may help to

review the basics of these components along with their key performance parameters before reviewing some of the latest product offerings in this area.

The simplest power divider is a component that splits one input signal into two in-phase output signals. More complex units can be constructed from cascades of this binary configuration, with even-numbered output ports, although dividers with an odd number of output ports, such as a three-way divider, are not uncommon (and often referred to as N-way power dividers, with N equal to an odd number). Power dividers can be formed by internally terminating a 180-deg. hybrid or through the use of Wilkinson or tapered-line configurations. Wilkinson dividers can be realized in microstrip or stripline technologies as a series of cascaded quarter-wavelength transformers. The transformers are used to transform the input impedance, typically 50 Ω , to an output impedance represented by the parallel combination of multiple outputs.

The simplest Wilkinson power divider

is a single-section component with 50- Ω input port, two 70.7- Ω quarter-wavelength transformers, and a 100- Ω

resistor. This simple configuration is relatively limited in bandwidth; more transformer sections and isolation resistors are needed for increased bandwidth, although the increased complexity also leads to increased size and insertion loss. An excellent application note from M/A-COM (www.macom.com), entitled simply "Power Dividers/Combiners" (application note M561) offers a concise four-page summary of power divider/combiner technology and the importance of various performance characteristics.

In an ideal two-way power divider, a 2-W input signal would result in two 1-W output signals. But resistors and terminations are not without loss, and even the best power dividers suffer some amount of insertion loss from input to output. Insertion loss can be readily calculated for a component as equal to $10\log(\text{input power/output power})$. In comparing power divider/combiner specifications, it should be pointed out that the actual insertion loss in a two-way divider would be comprised of the

JACK BROWNE
Publisher/Editor

3-dB division loss as well as the dissipative losses but, in most cases, manufacturers assume these division losses and present the insertion loss as that value above the nominal division loss (such as 3 dB in a two-way divider and 6 dB in a four-way divider).

Ideally, that two-way power divider would feature two output ports that are infinitely isolated from each other so that the division of power from the input to the output occurs without unwanted signal leakage between ports. In the real world, however, the isolation

is limited by variations in component values, manufacturing tolerances, and other factors. Still, high isolation is a measure of a high-quality power divider/combiner, typically exceeding 20 dB. As with insertion loss, the value of a power divider/combiner's isolation will vary with frequency, generally degrading with higher frequencies.

Two additional specifications that are important to power divider/combiner specifiers are amplitude balance (or unbalance) and phase balance (or unbalance). The two terms are also often denoted as amplitude tracking and phase tracking, although they represent simply the differences in amplitude and phase, respectively, between the output ports of a divider. Amplitude unbalance can be almost negligible in a two-way power divider/combiner, with performance levels of ± 0.3 dB or less not unusual. As the complexity of a divider/combiner increases, however, this specification tends to increase. An eight-way power divider/combiner, for example, would more typically exhibit amplitude unbalance of ± 10 dB between ports.

Phase unbalance will always be the larger number of the two parameters, since it is more difficult to control especially over wide frequency ranges. The small sizes of the latest drop-in and surface-mount power dividers/combiners, however, account for some impressive specifications. Traditional coaxial power dividers/combiners might show a phase unbalance specification of ± 10 deg. depending on bandwidth and frequency, with the value increasing as a function of increasing frequency and bandwidth. Drop-in power dividers/combiners such as the Xinger™ line of miniature components from Anaren Microwave (www.anaren.com) achieve good amplitude and phase tracking between output ports through their small sizes and well-controlled manufacturing tolerances. The company's model 4A1305 is a two-way, in-phase power divider that measures $0.560 \times 0.350 \times 0.081$ in. and operates from 1400 to 2600 MHz. It features broadband phase balance of 2.5 deg. with

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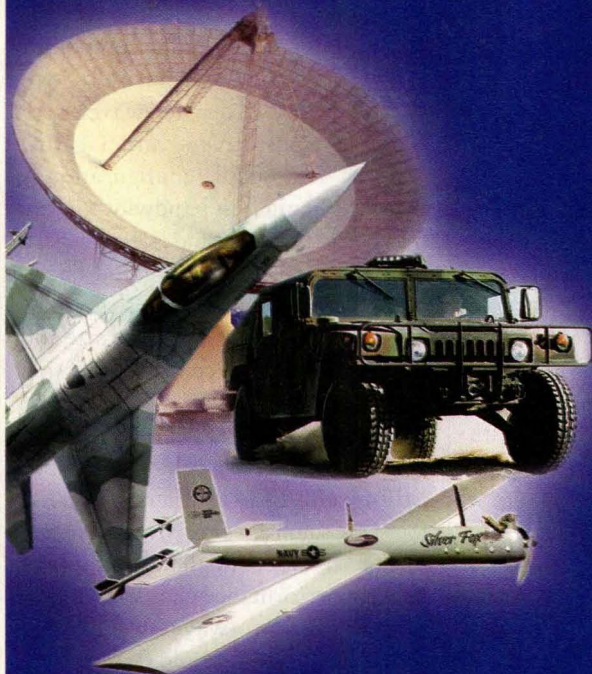
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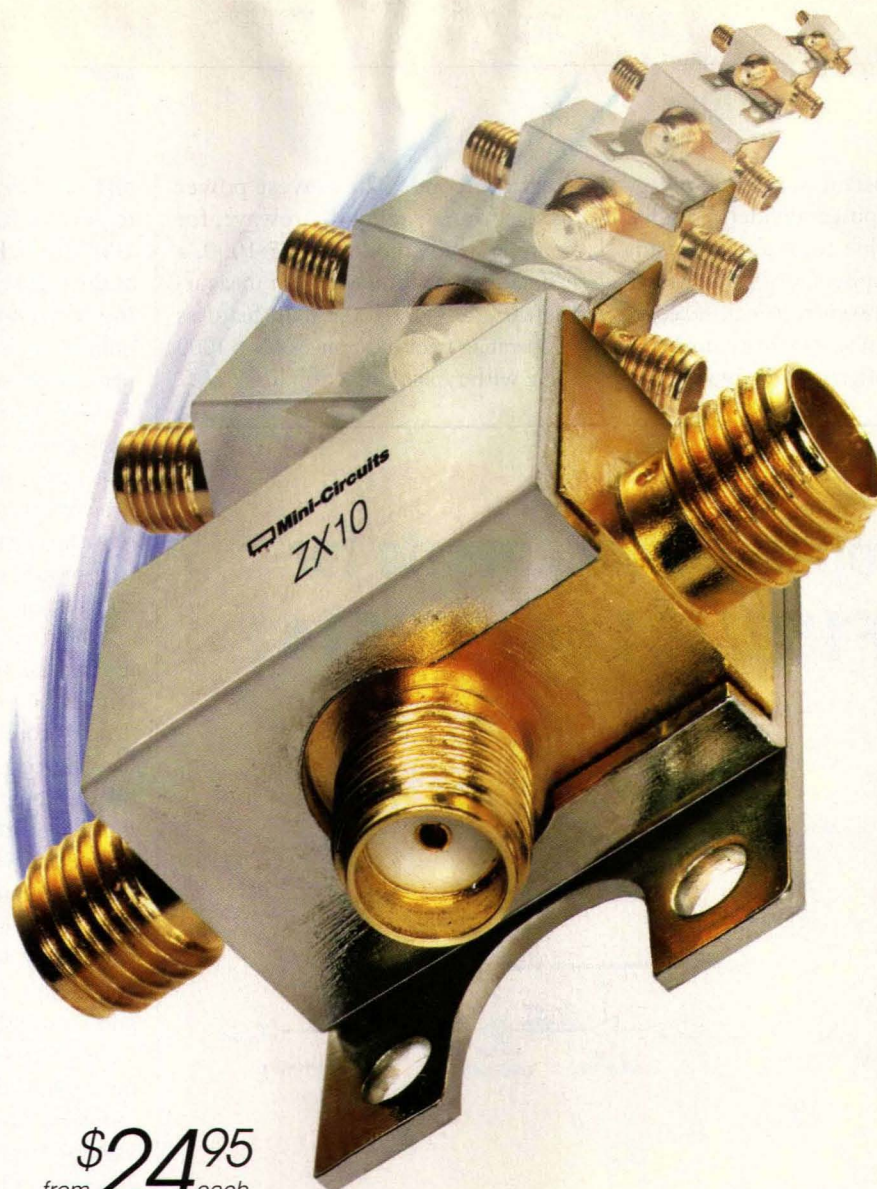
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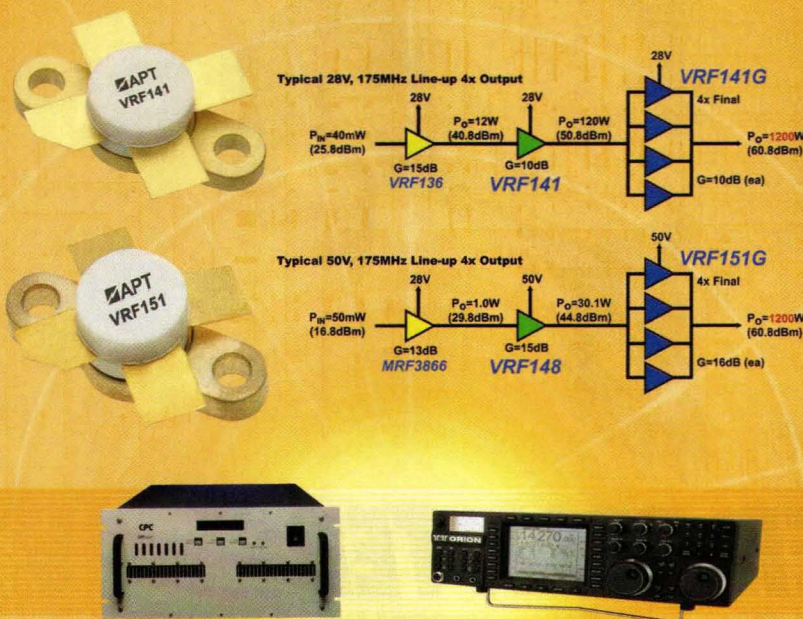
Such small power dividers/combiners are available from an increasing number of suppliers, including Merrimac Industries (www.merrimacind.com), Mini-Circuits (www.minicircuits.com), and Synergy Microwave ([\[synergymwave.com\]\(http://www.synergymwave.com\)\). The newest power divider from Synergy Microwave, for example, is the model SPD-5-1000, a surface-mount four-way unit measuring just \$0.8 \times 0.3 \times 0.2\$ in. It features an operating-frequency range of 5 to 1000 MHz with typical insertion loss of 0.7](http://www.syner-</p>
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dB from 5 to 50 MHz, 0.65 dB from 50 to 500 MHz, and 0.7 dB from 500 to 1000 MHz. Isolation is typically 23 dB at the higher frequencies and 27 dB at the low end. Maximum amplitude unbalance is 0.5 dB while maximum phase unbalance is 5 deg. The model SPD-5-1000 divider is designed to handle input power levels to 1 W. The company also offers power dividers/combiners in a variety of package types, including relay headers, leaded and leadless surface-mount packages, and large coaxial packages.

Merrimac's Multi-Mix microtechnology has been applied to the development of a series of miniature power dividers/combiners known as the Pico™ line. The company's Pico Z-series power dividers/combiners are fusion-bonded multilayer stripline assemblies that can be supplied in tape-and-reel format for surface-mount applications. In particular, the model PDD-2Z-1.7G is a two-way power divider/combiner that operates from 1.5 to 1.8 GHz with low loss and reasonable isolation.

Mini-Circuits, which offers one of the most extensive component lines in the industry, also supplies a tremendous variety of power dividers/combiners, including surface-mount and drop-in 50- and 75-Ω components and larger, higher-power coaxial units. The model SBB-2-23, for example, is a two-way surface-mount power divider/combiner that covers 2000 to 2300 MHz and measures just $0.2 \times 0.275 \times 0.070$ in. In spite of the small size, it achieves better than 20 dB isolation across its operating range with phase unbalance of better than 1 deg. When used as a power divider, the tiny component can handle 10 W power, although it is rated for internal (resistive) dissipation of 0.25 W. In contrast, the firm's model ZB4CS-700-10W power divider/combiner is a four-way coaxial unit that is rated for maximum internal power dissipation of 8 W. It operates from 400 to 700 MHz with impressive typical isolation of 25 dB and typical insertion loss of 0.35 dB. (The company's data sheets are among the few in the industry that show actual S-parameters for insertion loss, indicat-

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In addition to all the features of the Bravo line, the **Bravo S21** now has 2 ports to allow you to sweep filters and measure isolation between two circuits. The Cable Nulling feature is still there as is the EL Backlight. We have NEW software available for this line as well.

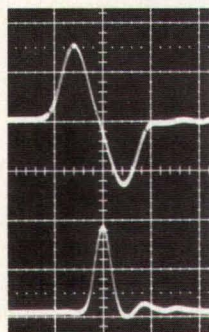
The **20/20 TDR** utilizes the proprietary technology of the Bravo line for a whole new level of TDR sophistication and accuracy at a standard Pulse TDR price. For less than \$1400 you can measure the EXACT impedance of your coax EVERY INCH out past 100 feet, and then less than 1 foot out to over 10,000 feet. Download the specsheets from:



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20 V/div, 1 ns/div

Avtech offers a comprehensive line of monocycle and impulse generators, offering amplitudes from 1-1000V, center frequencies as high as 5 GHz, and pulse widths as low as 130 ps. A partial selection is outlined below:

Monocycle Generators

Model	Vp-p	Center Freq.	PRF
AVE2-C	4V	3000-5000 MHz	1 MHz
AVD2-D-C	5V	100-250 MHz	100 MHz
AVB1-3-C	50V	400-900 MHz	100 kHz
AVB2-TB-C	400V	50-100 MHz	10 kHz
AVB3-TB-C	750V	75-100 MHz	10 kHz

Full details at www.avtechpulse.com/monocycle/

Impulse Generators

Model	Vmax	PW	PRF
AVH-S-1-C	10V	130 ps	1 MHz
AVMH-2-C	30V	400 ps	25 MHz
AVMH-4-C	100V	1 ns	10 MHz
AVG-3B-B	450V	2 ns	20 kHz
AVG-4C-C	1000V	8 ns	10 kHz

Full details at www.avtechpulse.com/impulse/

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ing the insertion loss with division losses included.)

It should be noted that manufacturers often present both amplitude unbalance and phase unbalance in several formats, including as a simple value representing a range, such as 0.5 dB or 6 deg., or as a deviation, such as ± 0.4 dB or ± 5 deg. It is important to recognize the format used by a given manufacturer and to "normalize" the specifications when performing a side-by-side comparison.

Additional specifications to compare when specifying power dividers/combiners include VSWR and power-handling capability. VSWR, or voltage standing wave ratio, is a measure of how well a component's input and output ports are matched to each other and to the outside world which, in high-frequency systems, is usually at a characteristic impedance of 50 Ω . [Of course, for cable-television (CATV) applications, the characteristic impedance is 75 Ω .] Simply put, the best-matched components will exhibit the lowest VSWR. As with many specifications, manufacturers often list both maximum and typical numbers, with values that vary as a function of frequency. In general, maximum VSWR numbers that are below 2.0:1 indicate good-quality materials and manufacturing processes, especially for broadband components. For example, four-way power dividers/combiners from ARRA (www.arra.com) with SMA connectors are available in frequency bands from 0.005 to 18.0 GHz. One of the company's broadest-frequency components in this line covers a range of 8 to 18 GHz with maximum insertion loss of 1 dB and minimum isolation of 17 dB. In spite of the wide frequency range, the maximum VSWR is a respectable 1.60:1.

Power-handling capability is a function of several factors, including the physical size of the component (and its ability to dissipate heat), the type of connectors, and how well the ports are matched. Obviously, a rugged coaxial power divider/combiner with machined aluminum housing will be able to dissipate more heat than a chip-sized drop-in or surface-mount power divider/combiner.

In terms of power, most manufacturers provide two levels of capability, average (continuous) power and peak (short-duration) power. The SMA four-way power dividers/combiners from ARRA, for example, are rated for 20 W average power but 1 kW peak power. ARRA, as with most manufacturers, presents these values based on the assumption that all ports are matched (output ports terminated in 50 Ω for a precisely balanced load). Under unmatched conditions, the limiting factor on a power divider/combiner's power-handling capability will be the ratings of the internal resistors (which are rated for about 0.5 W in the case of the ARRA four-way SMA units).

For nearly 40 years, Werlatone (Brewster, NY, www.werlatone.com) has been a company synonymous with high-power passive components. The company offers an extensive line of very high-power dividers/combiners with continuous power ratings in the kW range. The company's model D3897, for example, is a two-way divider/combiner that operates from

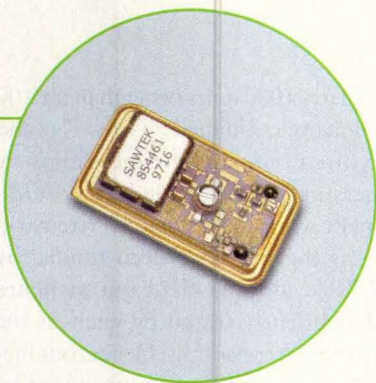
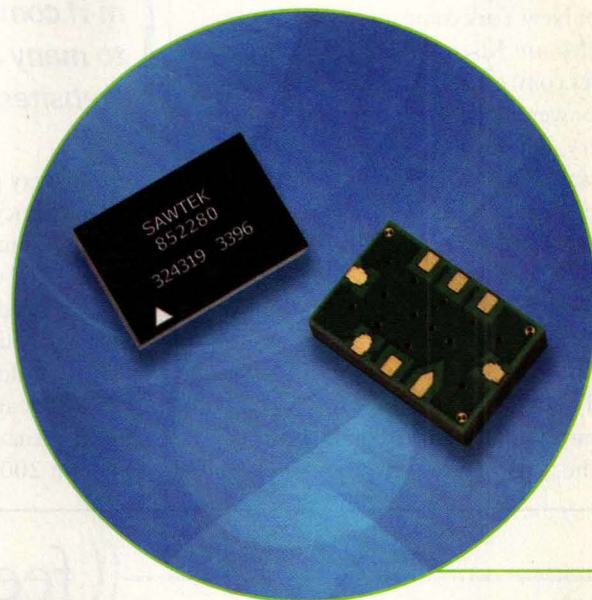
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Connecting the Digital World to the Global Network

500 to 1000 MHz with a power rating of 1 kW CW. To achieve this, the rugged design employs Type N connectors and achieves maximum insertion loss of 0.2 dB. The component also boasts impressive numbers for amplitude and phase unbalance, at 0.3 dB and 3 deg. maximum, respectively.

In terms of sheer bandwidth, another New York company, RLC Electronics (Mount Kisco, NY, www.rlcelectronics.com) offers some of the widest-range power dividers/combiners in the industry. The new model D-0640-W two-way power divider/combiner, for example, is a multisection Wilkinson design that ranges from 6 to 40 GHz with 15-dB minimum isolation and 1-dB maximum insertion loss. Over the broad range, the amplitude unbalance is ± 0.5 dB while the phase unbalance is ± 15 deg. The component is supplied with 2.92-mm K connectors to continuously cover the broad frequency range.

Using the same type of connectors, the model 4318-4 from Narda Microwave (www.nardamicrowave.com)

Visit the Microwaves & RF Product Data Directory website at www.m-rf.com for active links to many of the suppliers' websites.

is a four-way power divider/combiner with frequency range of 18 to 40 GHz. With maximum input/output VSWR of 1.90:1 and minimum isolation of 14 dB, the rugged component is a Wilkinson-type divider/combiner that is suitable for outdoor commercial and military applications. The 50-year-old high-frequency firm (see *Microwaves & RF*, June 2004, p. 33) offers a wide

range of power dividers/combiners, from simple two-way models to more complex 12- and 16-way units. The company has supplied higher-order dividers through 48-way and 64-way dividers with every type of connector from tiny 1.85-mm connectors through rugged EIA 7/16 high-power connectors.

The scope of this article prohibits listing all hundred or so suppliers of RF/microwave power dividers/combiners. Those wishing a representative listing are advised to visit the Microwaves & RF Product Data Directory website at www.m-rf.com, click on the Visitors button, log in (or skip log in for quicker access to the site), click on the "Search Manufacturers by Product Category" button, click on the "Components" menu selection, then select either the "Power Combiners" or "Power Dividers" category for an extensive listing of suppliers, many with active links to their websites. **MRF**

((feedback))

(continued from page 13)

intercept point is 10 dB above the third intercept point and the fourth-order intercept is above second- through fifth-order intercept points. It follows from this line of thinking that after considering third-order intermodulation products, the next-highest intermodulation product is usually the fifth-order when considering secondary effects. Even when considering tertiary effects, the systems designer will analyze seventh-order intermodulation effects before considering fourth-order intermodulation effects.

With respect to your second comment, as you stated the third-order intermodulation line in Fig. 1 in the article was incorrect. The slope of the third-order intermodulation interference should be 3:1 instead of 2:1. The corrected figure is shown on p. 13. The error was in the drawing of the graph. The analysis pre-

sented, including the charts, is correct.

MEMS And The MTT-S Show

► I WAS VERY intrigued to see your Editorial in the June issue of *Microwaves & RF* about MEMS at the MTT-S in Fort Worth ("MEMS Make Noise At MTT-S," p. 17), and I was shocked not to see mention of our company, Radant MEMS, Inc. We, like Dow Key, had an exhibit at the show, but we were down in the "hockey arena" area at booth 283. This was our first appearance as an exhibitor at MTT, and we were there to introduce our company to the marketplace as well as offer MEMS switches that are now in full production in a wafer-level package. Radant MEMS has been developing MEMS RF switches for the last two years, and these switches have a demonstrated lifetime exceeding 100 billion

cycles.

That is 1000 times better than the 100 million cycles claimed by Dow Key and the often omitted lifetime claims by others in the MEMS industry. Additionally, what makes this claim remarkable is that we have been funded by DARPA, who has had our switches independently tested by each of the three DoD service labs. Hence, our lifetime results have been reproduced by the Air Force Research Lab, the Army Research Lab, as well as the Naval Research Lab at each of their respective locales. Many military and commercial applications, such as phase shifters for radar or band-select switches for GSM cell phones require lifetimes on the order of 100 billion cycles, making the 100 million cycle switch far inferior.

John Maciel

Vice President and Chief Operating Officer
Radant MEMS, Inc.
Manager, Electromagnetics Technology
Radant Technologies, Inc.



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Output power to +20 dBm

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Ideal for outdoor applications

Hermetically sealed units



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Frequency Offset from Carrier	Phase Noise (dBc/Hz)			
	5 GHz	10 GHz	20 GHz	40 GHz
100 Hz	-86	-80	-74	-68
1 kHz	-116	-110	-104	-98
10 kHz	-124	-118	-112	-106
100 kHz	-126	-120	-114	-108
1 MHz	-141	-135	-129	-123
10 MHz	-150	-150	-146	-140



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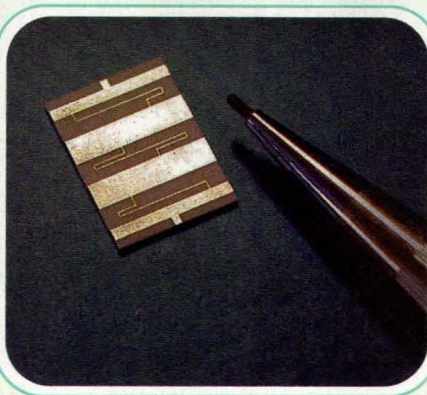
System Evaluates Next-Generation Wafers

DESIGNED FOR a wide range of current-voltage (I-V) and capacitance-voltage (C-V) on-wafer measurements on CMOS, bipolar, and GaAs integrated circuits (ICs), the model S470 is a ready-to-run parametric test system with RF test options to 40 GHz. The Model S470 bundled system comes in a 24-pin configuration, including probe card adapter and cabling, with full guarding and Kelvin connections to the probe needles. The versatile KTE software runs on a Sun controller using the Solaris UNIX operating system. Standard CMOS and BiCMOS measurement libraries are included, and new algorithms can be created with the included C-language compiler. On-site system installation and one-year warranty are included.

Keithley Instruments, Inc., 28775 Aurora Rd., Cleveland, OH 44139-1891; (888) 534-8453, (440) 248-0400, FAX: (440) 248-6168, e-mail: product_info@keithley.com, Internet: www.keithley.com.



KEITHLEY'S MODEL S470 PARAMETRIC TEST SYSTEM

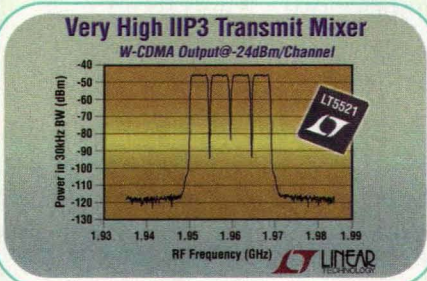


INTERNATIONAL MANUFACTURING SERVICE'S BANDPASS FILTER

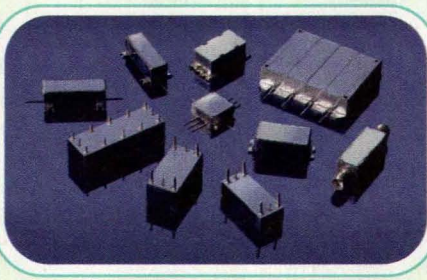
Drop-In Filter Passes 950 To 1450 MHz

COMPACT IN SIZE but not lacking in performance, a miniature bandpass filter has been developed for drop-in applications around 1200 MHz. With a passband of 1200 ± 250 MHz, the planar filter features at least 25 dB rejection at 2.5 GHz with at least as much rejection through 4.6 GHz. The miniature filter, which measures only $0.55 \times 0.44 \times 0.25$ in., achieves a VSWR of 1.0:1 over a 20-percent bandwidth. The insertion loss over the entire passband is a low 0.5 dB. The filter's design incorporates lumped/distributed parameters, is bilaterally symmetric, and contains seven sections with input and output ports matched to 50 Ω . The company offers similar filter configurations for a variety of custom frequency ranges and electrical requirements.

International Manufacturing Services, Inc., 50 Schoolhouse Lane, Portsmouth, RI 02871; (401) 683-9700, FAX: (401) 683-5571, e-mail: sales@ims-resistors.com, Internet: www.ims-resistors.com.



LINEAR TECHNOLOGY'S LT5521 ACTIVE MIXER



TRILITHIC'S MINIATURE SERIES FILTERS

Active Mixer Simplifies 3G Base-Station Design

DEVELOPED FOR third-generation (3G) cellular base stations, the LT5521 active mixer offers a wide frequency range from 10 MHz to 3.7 GHz, and operates with low local-oscillator (LO) drive level of only -5 dBm. Not only does this reduce LO radiation within the base station, it also controls LO-to-RF leakage to a low -42 dBm. The LT5521 operates with a single-ended LO drive and runs on a single supply voltage of +3.15 to +5.25 VDC. The conversion loss is a negligible 0.5 dB, with low noise figure. The LT5521 is supplied in a 16-pin 4×4 -mm surface mount quad-flat-pack (QFP) housing. The mixer is suitable for applications in wideband CDMA, UMTS, GSM, and PHS base-station transmitters. P&A: \$4.95 (1000 qty.); stock.

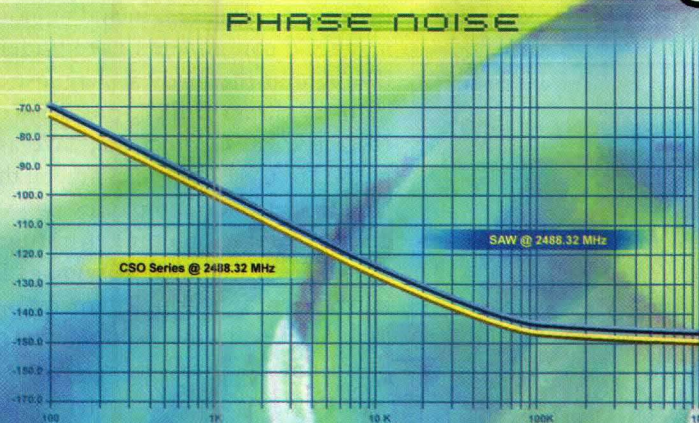
Linear Technology Corp., 1630 McCarthy Blvd., Milpitas, CA 95035-7417; (408) 432-1900, Internet: www.linear.com.

Rugged Filters Screen 10 MHz To 3.5 GHz

TINY FILTERS in the Miniature Series deliver high-performance characteristics such as high quality factor (Q) and low insertion loss in footprints much smaller than conventional tubular and LC-type filters. Models range from very low-cost TO-8 and surface-mount types to hi-rel and space-qualified models that can be screened for shock, vibration, acceleration to 50 g, wide temperature cycling, resistance to corrosion, and fine leak tests. Filter response characteristics include Chebyshev, Butterworth, Bessel, linear phase, Gaussian, and elliptic responses. Filter topology can be customized to deliver increased rejection on the low side of the passband or arithmetically symmetric rejection around the passband. Up to 12 sections can be incorporated, depending on the package style. Nearly all package styles (more than 17 standard types) can be hermetically sealed.

Trilithic, Inc., 9710 Park Davis Dr., Indianapolis, IN 46235, (317) 895-3600, Internet: www.trilithic.com.

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Dielectric Labs Acquires Voltronics

DIELECTRIC LABORATORIES (Cazenovia, NY) has announced the acquisition of Voltronics Corp. (Denville, NJ). Both

firms manufacture microwave capacitors—Dielectric Labs (www.dilabs.com) is known for its fixed-value

products and Voltronics (www.voltronicscorp.com) for its variable (trimmer) capacitors, including non-magnetic components used widely throughout the medical diagnostics industry. Brian DuPell, president of Dielectric Labs, comments, "We are pleased to have Voltronics among the Dover family of companies (www.dovercorporation.com). Although Voltronics will conduct business as an independent operating company, we look forward to the joint benefits of broader product, market, and customer opportunities."

Scott Newman, president of Voltronics, will remain to manage Voltronics as an independently operating company. Concerning the acquisition, Newman states, "It makes logical sense to create an alliance between a fixed and variable capacitor company. We have many common customers and can combine our sales organizations to achieve the best possible market penetration."

"Our manufacturing operation will remain in New Jersey, and all of our personnel, who, on average, have been with the company about 11 years, will continue on in their same positions."

Voltronics has been a family-run business since 1963. The company was founded by Scott Newman's father, Richard, in East Hanover, NJ. Scott Newman says, "My father had always said, if we were going to sell the company, Dover would be the one to sell it to." The acquisition process began about a year ago at the Microwave Theory & Techniques Symposium (MTT-S) in Philadelphia, PA, finally coming to contract on April 28th of this year, and closing on May 25th. Dover Technologies, with holdings that include Dow-Key Microwave, K & L Microwave, and Vectron, is part of the Dover Corp., a multibillion-dollar company that consists of more than 50 companies and is publicly traded on the New York Stock Exchange. **MRF**

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Phase Noise: -172 dBc



FE-205A - 405A - 505A
Rubidium Stability from High Performance OCXOs



FE-101A
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Controlled Design
Warm up less than 2 min.



FE-103A
Double Oven Design
Excellent Stability: $1 \times 10^{-11}/\text{sec}$

RUBIDIUM STANDARDS



Model FE-5600M
Military with Excellent Environmental Specifications



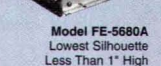
Model FE-5652A
High Temperature Operation: -40° C to +85° C



Model FE-5650A
Smallest Package
3" x 3" x 1.4"



Model FE-5660A
Fits Existing Sockets

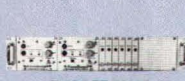


Model FE-5680A
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A militarized, high Reliability RF distribution system for satellite ground stations and shipboard, mobile and laboratory applications.



**Model FE-7913A
Model FE-7914A**
Low Noise, High Isolation Signal Distribution Systems



Model FE-7923A
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Frequency Electronics, Inc. is a high technology research, engineering and manufacturing company. Its capabilities are in precision frequency and time generation, control and distribution components, instruments and subsystems. FEI manufactures frequency standards utilizing quartz, rubidium, and cesium for satellite applications, commercial communications systems and defense applications.

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OCXO



TCXO and
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Temperature
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Daily Aging
<1x10⁻¹¹/day

High Stability
Remotely Settable



Daily Aging
<2 to 3x10⁻¹¹/day

Triple Redundant
Master Local
Oscillator



5 MHz to 100 MHz

Class S & B Custom
Hybrid Capability



Multiple Technologies
DC to 22 GHz

DC/DC Converter



Small size, Light Weight,
to 1% Regulation,
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and Distribution
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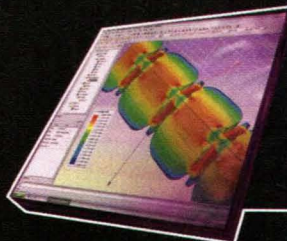
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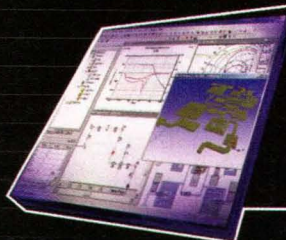
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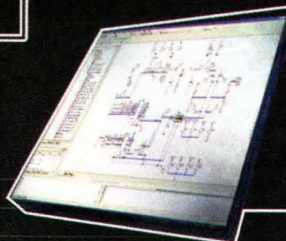
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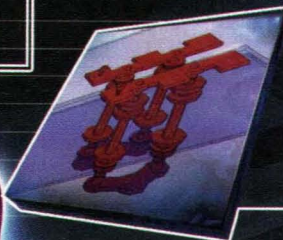
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CONTRACTS

TECOM Industries, Inc.—Has been awarded a contract by Boeing for delivery of 15 INMARSAT T-4000 Aero-H High Gain Antennas (HGA) to meet FY '05 C-17 Secure Enroute Communications Program-Improved (SECOMP-I) program requirements. Boeing is the prime contractor to integrate the US Army's Secure Enroute Communications Package—Improved (SECOMP-I) into the C-17 Globemaster III aircraft. Follow-on awards are scheduled for FY '06 and FY '07 for 15 ship sets per year totaling \$2 million.

L-3 Communications ESSCO—Announced that they have been awarded a major development contract by the Massachusetts Institute of Technology's Lincoln Library to design, fabricate, and install a series of sophisticated technology upgrades to the 37-meter-diameter Haystack Radio Telescope located in Westford, MA. The large-scale contract, to be executed over the next three years, will include design, fabrication, and field installation efforts.

BAE Systems—Has been awarded a \$34.5 million contract from the Office of Naval Research to manufacture 132 high-frequency (HF) transmitters for installation in the High Frequency Active Auroral Research Program's (HAARP) phased-array antenna system.

The HAARP program collects and assesses data to advance knowledge of the physical and electrical properties of the Earth's ionosphere.

REMEC, Inc.—Has received an initial \$9.9 million production contract from Raytheon Missile Systems for the TOW (Tube-Launched, Optically Tracked, Wire-Guided) missile second-generation upgrade program. This contract is a result of Raytheon's recent demonstrated success to prove feasibility to add expanded capability to the TOW weapon system. With the production option for additional microwave units, the total contract value has a potential of greater than \$17 million for the first three production lots for REMEC. This program is the result of an earlier development success for the TOW Gen 1 system in which over 1000 production upgrade units were produced by REMEC for this missile configuration. The new TOW Gen 2 production contract includes delivery of 1501 Integrated Microwave Assemblies (IMAs), production rate tooling, and long lead material funding for an additional 807 IMAs. Delivery is scheduled to begin later this year with contract completion in 2006.

FRESH STARTS

RF Micro Devices, Inc.—Announced that it has established an assembly facility at its Beijing, China location to provide internal module packaging capabilities.

The new assembly operation is expected to become fully operational in the December 2004 quarter.

TEMEX—Granted BFi OPTiLAS the representation and the distribution of some of its RF product lines. Both companies have a strong willingness to develop such products in the European market. Those main lines are SAW filters (short-range devices), waveguide and coaxial isolators/circulators, and PIN diodes.

Microwave Circuits, Inc.—Has decided to relocate its headquarters from Washington, DC to Lynchburg, VA. Through a \$2.1 million investment, the company will create 200 new, high-paying jobs for Lynchburg. Located in the Kemper Building in downtown Lynchburg, Microwave Circuits will manufacture its new, patent-pending technology for use in homeland security and Department of Defense (DoD) applications.

Hittite Microwave Corp.—Announced the appointment of a new sales representative firm to serve customers in the Eastern Canada provinces of Ontario, Quebec, New Brunswick, Prince Edward Island, and Nova Scotia. Repwave, Inc., headquartered in Ottawa, Ontario, is a technical sales agency providing sales representation for industry-leading manufacturers of RF/microwave and optical components. Repwave's sales organization has over 30 years of professional sales experience covering wireless communications and optical networks.

Repwave can be contacted by phone at (613) 270-9811, via fax at (613) 270-9812, or e-mail at frank.masciotra1@sympatico.ca.

BI Technologies—Has added Weiss Co. to its list of authorized sales representatives. With more than 35 years of sales and service experience in Canada, Weiss Co. represents several complementary passive, electro mechanical, and active electronic product lines for a wide range of customer needs.

With sales offices in Montreal, Ottawa, Toronto, and Vancouver, Weiss Co. will represent BI's full line of electronic and magnetic components, including trimming and precision potentiometers, position sensors, turns counting dials, resistor networks, integrated passive networks, switches, transformers, inductors, hybrid microelectronics, and custom integration products.

For more information on Weiss Co., see their website at www.weissco.ca.

Elcoteq Network Corp.—Announced that it has joined the WiMAX Forum. As a member of the WiMAX Forum, Elcoteq is dedicated to supporting its clients and the communications industry by manufacturing products and providing supporting services that adhere to the IEEE 802.16 standard.

Applied Wave Research, Inc.—Announced a corporate agreement with Ashvattha Semiconductor, Inc. for the company to purchase AWR's Analog Office design suite. Ashvattha will utilize the Analog Office software for the design of its RF integrated circuits (RF ICs), which integrate multiple standards on a single chip.

Ashvattha is a provider of highly integrated RF chips for wireless device manufacturers. **MRF**

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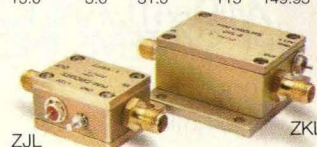
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Model	Freq (MHz)	Gain (typ) Midband (dB)	Flat (±dB)	Max. P _{out} 1 (dBm)	Dynamic Range (Typ @2GHz ²) NF(dB) IP3(dBm)	Price Sea. (1-9)
ZJL-5G	20-5000	9.0	±0.55	15.0	8.5 32.0	80 129.95
ZJL-7G	20-7000	10.0	±1.0	8.0	5.0 24.0	50 99.95
ZJL-4G	20-4000	12.4	±0.25	13.5	5.5 30.5	75 129.95
ZJL-6G	20-6000	13.0	±1.6	9.0	4.5 24.0	50 114.95
ZJL-4HG	20-4000	17.0	±1.5	15.0	4.5 30.5	75 129.95
ZJL-3G	20-3000	19.0	±2.2	8.0	3.8 22.0	45 114.95
ZKL-2R7	10-2700	24.0	±0.7	13.0	5.0 30.0	120 149.95
ZKL-2R5	10-2500	30.0	±1.5	15.0	5.0 31.0	120 149.95
ZKL-2	10-2000	33.5	±1.0	15.0	4.0 31.0	120 149.95
ZKL-1R5	10-1500	40.0	±1.2	15.0	3.0 31.0	115 149.95

NOTES:

1. Typical at 1dB compression.
2. ZKL dynamic range specified at 1GHz.
3. All units at 12V DC.



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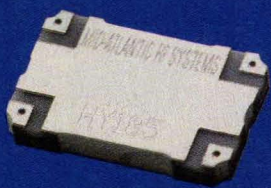
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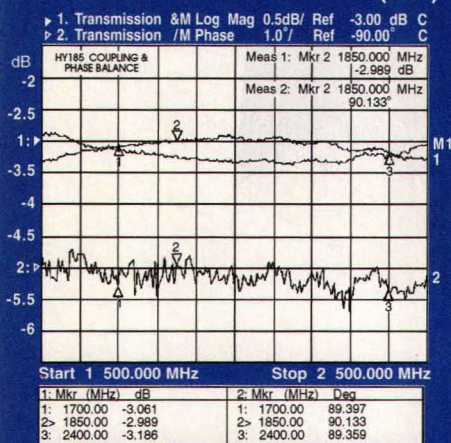


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Spectrum Control Appoints Teifer To Development Post

Spectrum Control's Power Management Systems Group has named JOE TEIFER as their new director of business development and strategic accounts. Teifer will focus on growing the company's business with service providers and government resellers.

Janos Technology, Inc.—ROBERT WINKLER to system sales engineer; formerly business development specialist and major account manager for Aerospace and Defense customers at Corning's Diamond Turning Division.

Cimetrix, Inc.—DENNIS P. GAUGHER to CFO; formerly accounting and auditing partner with Deloitte & Touche.

TeraChip—STEVE PERNA to the board of directors; formerly vice president and general manager of PMC-Sierra's Service Provider Division.

Clarus Systems, Inc.—RICHARD WHITEHEAD to CTO; formerly vice president of technology. Also, ROBERT BOND to the board of directors; formerly COO at Rational Software Corp.

Park Electrochemical Corp.—ANTHONY W. DIGAUDIO to vice president of quality; formerly product director.

Modelithics, Inc.—DICK WHISLER to director of operations; formerly served as vice president and general manager for several electronic-instrumentation and electronic-component companies.

IMS Connector Systems GmbH—GÜNTER MÖBIUS to managing director; formerly member of the executive board of Sauter AG.

Stretch, Inc.—REYNETTE AU to vice president of marketing; formerly president and CEO for Triscend Corp.

Intellon Corp.—ANDREAS MELDER to senior vice president of sales, marketing, and business development; formerly COO at Clarisay, Inc.

National Security Telecommunications Advisory Committee (NSTAC)—PATRICIA RUSSO to the role of vice chairman; continues as chairman and CEO of Lucent Technologies.

Raytheon Co.—NANCY H. GREER to vice

president of finance and CFO for Raytheon Intelligence and Information Systems (IIS); formerly senior vice president and CFO at Alcatel North America.

Schneider Electric North American Operating Division—MARY FRANCES COX to vice president of operations; formerly vice president of manufacturing operations at Schneider Electric.

Powerhouse Technologies Group, Inc.—DAVID R. WELLS to vice president for finance operations; formerly acting COO/CFO at Insurance Services of America.

TECOM Industries, Inc.—MAGDY MICHAEL to senior marketing manager; formerly senior director of worldwide sales and marketing for California Amplifier's Satellite Division.

Park Electrochemical Corp.—EDDIE MOK to Asia Pacific director for OEM marketing and technology; formerly country service manager in China. Also, LEENA GULIA to senior OEM marketing engineer; formerly OEM marketing engineer.

CSR plc—RICHARD ORD to vice president of the Bluetooth Business Unit; formerly vice president at VLSI Technology and Philips Semiconductor.



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Indium Corp.—LEO M. DEVINE to marketing development manager for Wave Solder Products; formerly marketing communications manager. **MRF**

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InGaP HBT



HMC311ST89 HMC311LP3

- ◆ DC - 6.0 GHz
- ◆ +16 dBm P1dB Output Power
- ◆ 16 dB Gain
- ◆ +32 dBm Output IP3
- ◆ SOT89 or QFN Packages



SiGe & InGaP HBT GAIN BLOCKS



PART NUMBER	TECHNOLOGY/PACKAGE	BANDWIDTH (MHz)	GAIN (dB)			P1dB (dBm)			Output IP3 (dBm)			NF (dB)
			850 MHz	1950 MHz	3500 MHz	850 MHz	1950 MHz	3500 MHz	850 MHz	1950 MHz	3500 MHz	
HMC476MP86	SiGe / Micro-X	6000	20	17	13	13	12	13	25	25	26	2.5
HMC479MP86	SiGe / Micro-X	5000	15	13	11	19	17	14	34	32	28	4.0
HMC479ST89	SiGe / SOT89	5000	15	13	11	18	16	14	34	32	28	4.1
HMC481MP86	SiGe / Micro-X	5000	20	17	13	20	18	15	33	33	29	3.5
HMC481ST89	SiGe / SOT89	5000	20	17	13	20	18	15	33	33	29	3.6
HMC311ST89	InGaP / SOT89	6000	15	15	15	16	15	14	32	30	27	4.7
HMC311LP3	InGaP / QFN	6000	15	14.5	14	16	15	14	32	30	27	4.5
HMC313	InGaP / SOT26	6000	16	16	16	14	13	12	28	26	23	6.5
HMC315	InGaP / SOT26	7000	14	14	14	16.5	15.5	14	34	29	27	6.5

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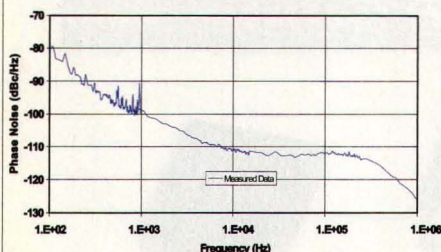
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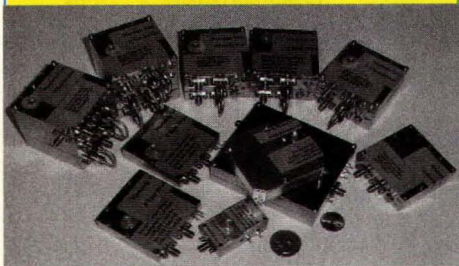
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Phase Noise at 23 GHz (Typical)

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1 KHz	-100 dBc/Hz
10 KHz	-110 dBc/Hz
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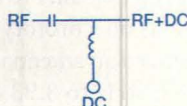
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See our 244 page RF/IF Designer's Guide in EEM (Electronic Engineers Master)

Studying Cellular-Telephone Emissions On The Head

CELLULAR-TELEPHONE EMISSIONS have been studied extensively according to specific-absorption-rate (SAR) models of the human head. To take these studies one step further, Hsing-Yi Chen and Han-Peng Yang of the Department of Communications Engineering of Yuan Ze University (Taoyuan-shian, Taiwan) have examined the local maximum SAR induced in spherical, cubical, coarse, and realistic human-head models exposed to a cellular telephone using the finite-difference time-domain (FDTD) method of analysis at 900 and 1800 MHz. The authors note that for bioelectromagnetic applications, the FDTD method has been found to be extremely versatile and has been used for whole-body and partial-body studies due to spatial uniform or nonuniform electromagnetic (EM) fields.

In their modeling of the human head, special attention was paid to the dielectric constant and conductivity of the head, the cellular telephone, and the excitation of the antenna. The

researchers based their studies on the effects of different human head shapes and the influence on SAR. In one of their models, for example, the head wraps around three sides of the cellular telephone and consists of a core of bone surrounded by a layer of muscle. The equivalent dielectric constant, conductivity, and mass density are determined by assuming different volume fractions for the bone and muscle at 900 and 1800 MHz. The researchers found that, while the shape of the human head model played a minor role in the final SAR, the homogenous human head models led to higher SAR values than nonhomogenous human head models. Other factors to be considered were the positioning of the antenna and the relative distance from the telephone to the head. See "SAR Affected by Shapes and Electrical Properties of the Human Head Exposed to a Cellular Telephone," *Microwave and Optical Technology Letters*, July 5, 2004, Vol. 42, No. 1, p. 1.

Novel Discone Antenna Serves UWB Systems

DISCONE ANTENNAS ARE OFTEN USED to monitor wide frequency bands. This type of antenna generally has a low-cutoff/high-cutoff bandwidth ratio of 1/8 for the UHF band. The critical matching factor for broad bandwidth is the gap height between the antenna disk and the cone skirt. Researchers Jinu Kim and Seong-Ook Park of the School of Engineering, Information and Communications University (Daejeon, Korea) explored the design and optimization of a double-discone antenna configuration for ultrawideband (UWB) communications applications. The double-discone antenna combines the traits of a conventional large discone antenna with bandwidth of 300 MHz to 2.4 GHz and a smaller design with bandwidth from 2.4 to 9.0 GHz.

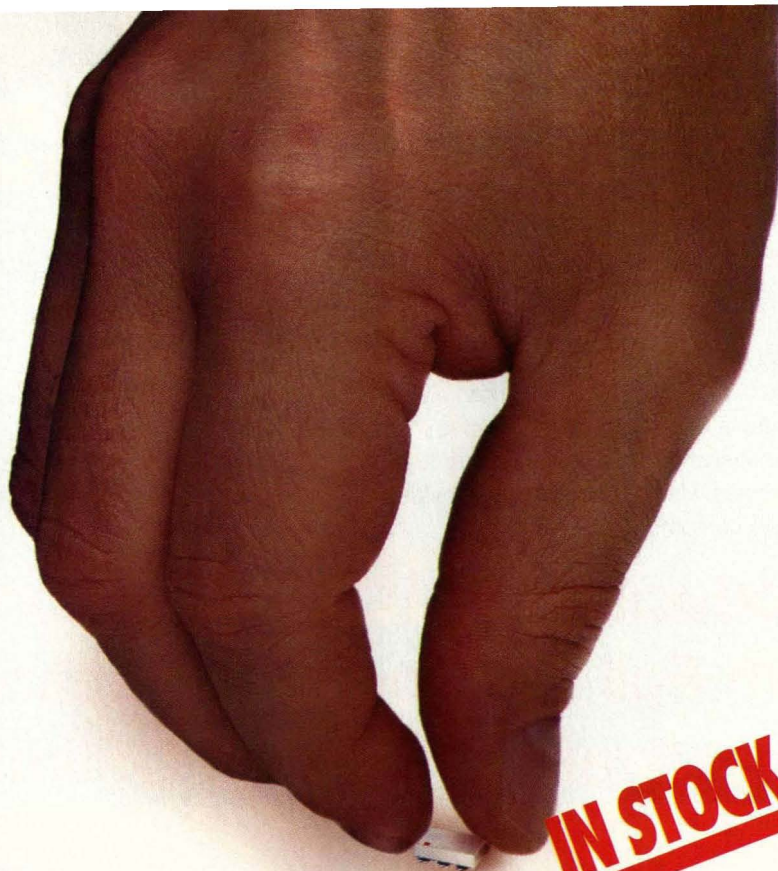
Using finite-element-method (FEM) analy-

sis tools to design the antenna, and a commercial vector network analyzer (model 8510C) from Agilent Technologies (Santa Rosa, CA) to perform measurements on a prototype design, the researchers developed an antenna with 30:1 bandwidth from 282 MHz to 8.93 GHz. The antenna VSWR over that wide range was a respectable 2.0:1 or less (very close to simulated values). The antenna was found to provide even radiation patterns as wide as 100 to 140 deg. The measured gain was found to peak at 7 dBi at 4 GHz, and exceed 5 dBi for most of the covered bandwidth, with simulated gain closely approaching the measurement values within an accuracy of better than 1 dB. See "Novel Ultra-Wideband Discone Antenna," *Microwave and Optical Technology Letters*, July 20, 2004, Vol. 42, No. 2, p. 113.

Patch Antenna Fits WLAN Access Points

WIDE ANTENNA RADIATION PATTERNS CHARACTERIZING high-speed, are needed for wireless-local-area-network (WLAN) access points. Often monopole or dipole antennas are used for this purpose, with good omnidirectional patterns. But Saou-Wen Su and fellow researchers from the Department of Electrical Engineering at the National Sun Yat-Sen University (Kaohsiung, Taiwan) discovered that a properly designed patch antenna can also provide a wide horizontal radiation pattern that is well suited for WLAN access points.

The patch antenna consists of an inverted-L narrow radiating patch and an inverted-V ground plane. The compact design provides a 3-dB beamwidth of 40 deg. in the E-plane at 2442 MHz and 150 deg. in the H-plane at the same frequency. The on-axis gain for both beamwidths is 3.7 dBi. The 2.4-GHz antenna is about one-half the size of a conventional patch antenna. See "A Patch Antenna with a Wide Horizontal Radiation Pattern for WLAN Access Point," *Microwave and Optical Technology Letters*, July 20, 2004, Vol. 42, No. 2, p. 161.



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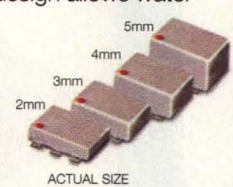
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ADE* TYPICAL SPECIFICATIONS:

MODEL	LO Power (dBm)	Freq. (MHz)	Conv. Loss Midband (dB)	L-R Isol. Midband (dB)	IP3 @ Midband (dBm)	Height (mm)	Price (Sea. Qty. 10-49)
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ADE-3L	+3	0.2-400	5.3	47	10	4	4.25
ADEX-10L	+4	10-1000	7.2	60	16	3	2.95
ADE-1	+7	0.5-500	5.0	55	15	4	1.99▲
ADE-1ASK	+7	2-600	5.3	50	16	3	3.95
ADE-2	+7	5-1000	6.67	47	20	3	1.99▲
ADE-2ASK	+7	1-1000	5.4	45	12	3	4.25
ADE-6	+7	0.05-250	4.6	40	10	5	4.95
ADEX-10	+7	10-1000	6.8	60	16	3	2.95
ADE-12	+7	50-1000	7.0	35	17	2	2.95
ADE-4	+7	200-1000	6.8	53	15	3	4.25
ADE-14	+7	800-1000	7.4	32	17	2	3.25
ADE-901	+7	800-1000	5.9	32	13	3	2.95
ADE-5	+7	5-1500	6.6	40	15	3	3.45
ADE-5X	+7	5-1500	6.2	33	8	3	2.95
ADE-13	+7	50-1600	8.1	40	11	2	3.10
ADE-11X	+7	10-2000	7.1	36	9	3	1.99▲
ADE-20	+7	1500-2000	5.4	31	14	3	4.95
ADE-18	+7	1700-2500	4.9	27	10	3	3.45
ADE-3GL	+7	2100-2800	6.0	34	17	2	4.95
ADE-3G	+7	2300-2700	5.6	36	13	3	3.45
ADE-28	+7	1500-2800	5.1	30	8	3	5.95
ADE-30	+7	200-3000	4.5	35	14	3	6.95
ADE-32	+7	2500-3200	5.4	29	15	3	6.95
ADE-35	+7	1600-3500	6.3	25	11	3	4.95
ADE-18W	+7	1750-3500	5.4	33	11	3	3.95
ADE-30W	+7	300-4000	6.8	35	12	3	8.95
ADE-1LH	+10	0.5-500	5.0	55	15	4	2.99
ADE-1LHW	+10	2-750	5.3	52	15	3	4.95
ADE-1MH	+13	2-500	5.2	50	17	3	5.95
ADE-1MHW	+13	0.5-600	5.2	53	17	4	6.45
ADE-10MH	+13	800-1000	7.0	34	26	4	6.95
ADE-12MH	+13	10-1200	6.3	45	22	3	6.45
ADE-25MH	+13	5-2500	6.9	34	18	3	6.95
ADE-35MH	+13	5-3500	6.9	33	18	3	9.95
ADE-42MH	+13	5-4200	7.5	29	17	3	14.95
ADE-1H	+17	0.5-500	5.3	52	23	4	4.95
ADE-1HW	+17	5-750	6.0	48	26	3	6.45
ADEX-10H	+17	10-1000	7.0	55	22	3	3.45
ADE-10H	+17	400-1000	7.0	39	30	3	7.95
ADE-12H	+17	500-1200	6.7	34	28	3	8.95
ADE-17H	+17	100-1700	7.2	36	25	3	8.95
ADE-20H	+17	1500-2000	5.2	29	24	3	8.95

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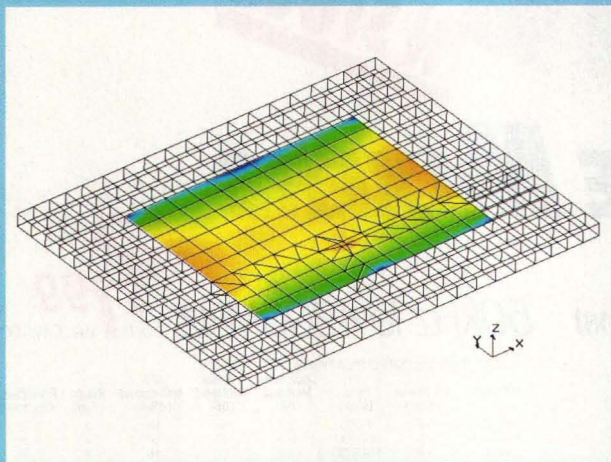
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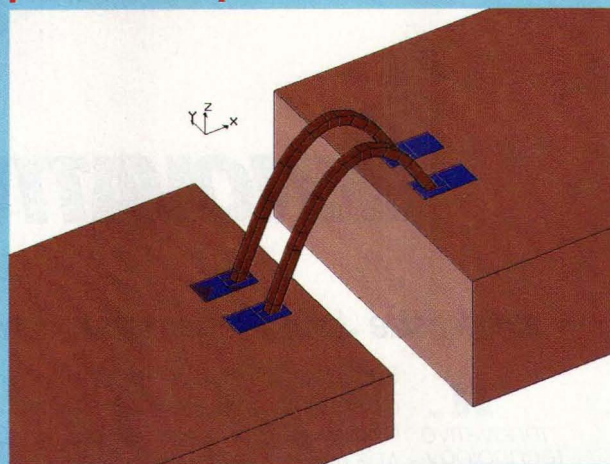
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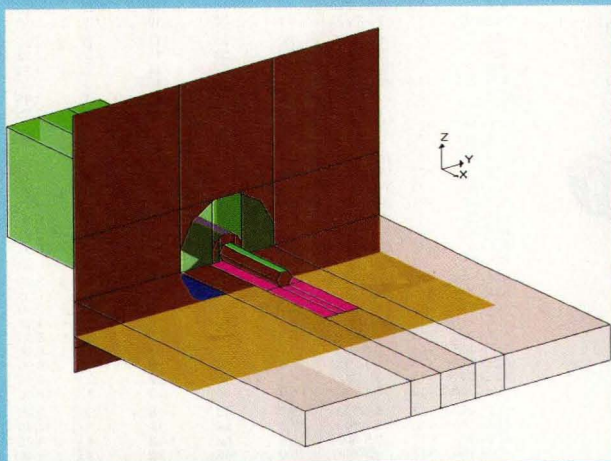
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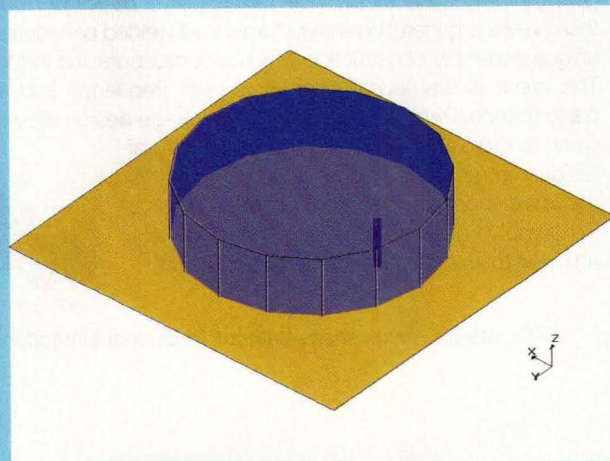
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ESD-Hardened Device Fuels UHF Amplifiers

This rugged bipolar transistor has been designed to withstand high levels of ESD making it well suited for UHF automotive electronics applications.

automotive applications in the ultra-high-frequency (UHF) band require transistors that provide good RF performance but are also robust. The BFP460 from Infineon Technologies (Munich, Germany) is a general-purpose transistor that is electrostatic-discharge (ESD)-hardened for such applications. It benefits from a silicon-bipolar process technology with 23-GHz transition frequency and can safely withstand

and tire-pressure monitoring systems (TPMS). Each of these systems require RF building blocks having good performance, low cost, and high levels of ruggedness/robustness (Table 1).

ESD pulses of 1500 W between any pair of terminals. The effectiveness of the new device will be demonstrated in a UHF low-noise amplifier (LNA) that is ideal for automotive use.

As RF devices have scaled to smaller dimensions for higher-frequency use, they tend to exhibit higher current densities (approximately 3 mA/ μm^2 or 300,000 A/cm² at a typical transistor operating point) while the breakdown voltage has dropped (from typically 50 V to around 3 V). The breakdown volt-

A variety of automotive systems now make use of RF technology, including remote-keyless entry (RKE), Global Positioning System (GPS), Satellite Digital Audio Radio Services (SDARS),

JAKOB HUBER

Title

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**Table 1: A sampling of RF systems
for automotive applications**

FREQUENCY RANGE	DESCRIPTION	COMMENTS
315 MHz (NAFTA) 434 MHz (Europe)	Remote keyless entry (RKE) Tire-pressure monitoring systems (TPMS)	TPMS in US, RKE worldwide
1.575 GHz	Global Positioning System (GPS)	Location/navigation
2.400 to 2.483 MHz	Bluetooth, radio-frequency identification (RFID) toll tags	e.g., Bluetooth headset for cellular phone "hands free," toll collection
5.850 to 5.925 GHz	Dedicated short-range communications ("DSRC") in NAFTA	Safety (e.g., over-height truck warning, railway—roadway warning, etc.), toll collection, weather and road info, etc.
23.9 to 24.7 GHz	Automotive radar	Safety—e.g., collision avoid ance, adaptive cruise control

UHF MODEMS

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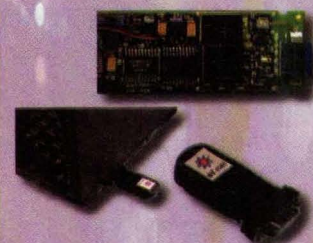
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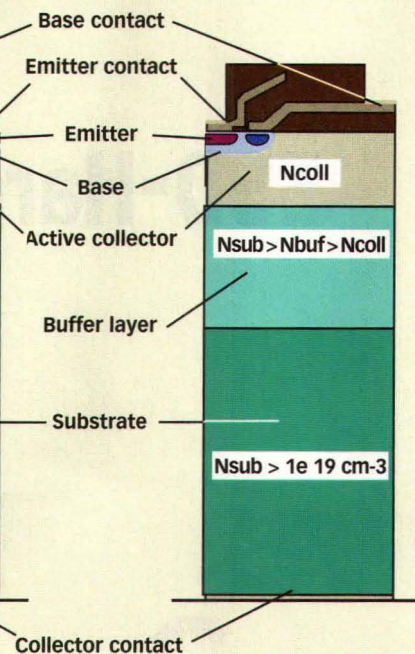
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DESIGN

1. The addition of a medium-doped buffer layer (right) to a conventional bipolar transistor design (left) improves the device ruggedness with respect to ESD pulses.

age as well as the optimum current density is determined by the thickness and the doping of the collector. For a high transition frequency, the collector must be kept thin. For high gain, all internal parasitic capacitances must be kept small, which is a driving factor for shrinking lateral dimensions, but also makes a transistor more sensitive to ESD damage.

Rigorous study of transistor ESD failure mechanisms have shown that there is room for improvement in device ESD robustness. The discrete BFP460 transistor incorporates some of the

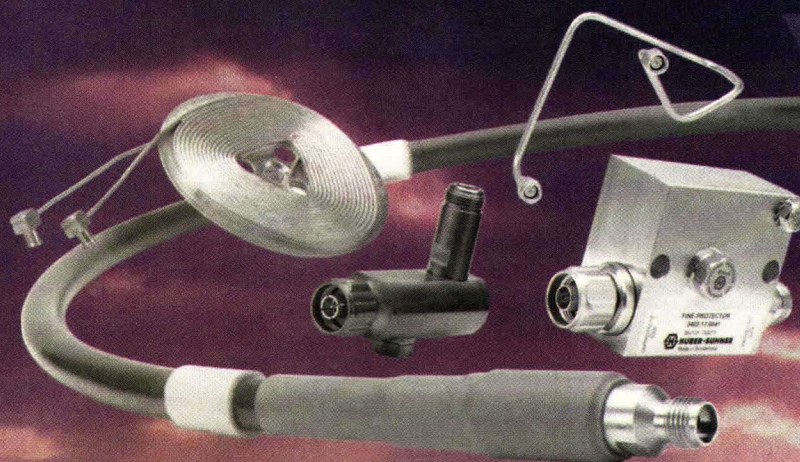


findings of such research to withstand 1500-V human-body-model (HBM) pulses while achieving a cutoff frequency of 23 GHz, maximum stable gain of 17.5 dB and minimum noise figure of 1.1 dB at 1.8 GHz.

The most widely used standard for ESD testing is the HBM detailed in MIL STD 883D. In this standard, a 100-pF capacitor is charged to a reference voltage (V_{REF}). The reference voltage power

Table 2: Summarizing BFP460 feedback LNA performance

PARAMETER	RESULT	COMMENTS
Frequency range	<300 MHz to > 1 GHz	315-, 345-, 390-, 434-, and 900-MHz ISM bands covered
DC current consumption	4.5 mA typical	
Supply voltage	5.0 V	Can be used down to 2.5 V
Gain	15.9 dB at 315 MHz 15.5 dB at 434 MHz 13.5 dB at 900 MHz	
Noise figure	1.4 dB at 315 MHz 1.4 dB at 434 MHz 1.6 dB at 900 MHz	
Input power (1-dB comp.)	-21 dBm at 315 MHz	
Input third-order intercept	-11.4 dBm at 315 MHz	
Input return loss	11.8 dB at 315 MHz 11.5 dB at 434 MHz 10.3 dB at 900 MHz	Good broadband match
Output return loss	18.1 dB at 315 MHz 16.9 dB at 434 MHz 13.6 dB at 900 MHz	Good broadband match
Reverse isolation	21.4 dB at 315 MHz 21.3 dB at 434 MHz 20.5 dB at 900 MHz	



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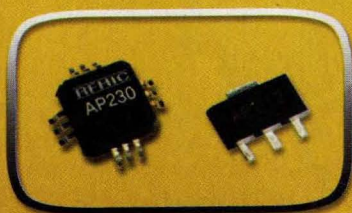


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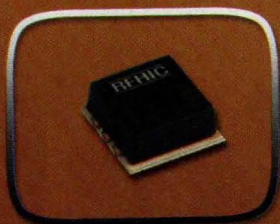


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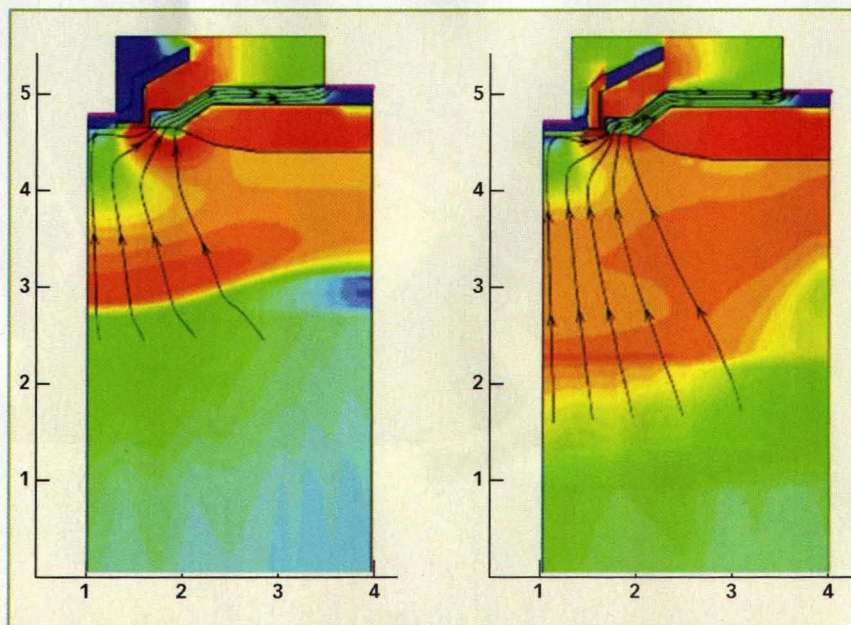
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DESIGN



2. This comparison of field distributions for an ESD pulse shows the even current distribution for the device with the buffer layer (right) compared to a conventional device without buffer layer (left).

supply is then disconnected, and the capacitor is discharged while connected through a series 1500- Ω resistor to the device under test (DUT). Reference voltages as low as 100 V are used for low-noise transistors with small device geometries and higher sensitivity to ESD, while voltages to 5000 V are used for older, lower-performance, larger-geometry transistors (Tables 1 and 2 in ref. 4). A DUT is considered "rated" for a particular ESD level when it shows no degradation or failure when subjected to such tests at that level of V_{REF} . Typically, such tests have been performed on packaged devices, although ESD testing is now also performed at the on-wafer chip level.

An ESD pulse can best be understood as a rapid surge of current within the device. For a first-order approximation, it is valid to assume that this event occurs too quickly to permit heat to spread or dissipate within the device experiencing this current surge. As a result, the temperature increase resulting from the ESD induced current surge is proportional to the square of the current density, and there exists a limit current density level beyond which actual localized melting of the device's silicon occurs. It is in fact this melting

of the silicon material which leads to device failure. As current density is the key item leading to device failure, transistors with a large emitter periphery or large area are more rugged than smaller ones. Contrary to common belief, there is little correlation between a transistor's collector-emitter breakdown voltage (V_{CEO}) and its resistance to ESD damage.

For improved robustness, designers of RF integrated circuits (RF ICs) have developed internal ESD protection structures which help shield the ESD-sensitive RF input and output terminals from harmful ESD events.^{1,2} Unfortunately, these ESD-protection structures also "load" the RF terminals with stray capacitance, inductance, and losses, thereby causing degradation in performance and making such structures unsuitable for use with discrete devices (where higher performance is expected).

In a three-terminal device like a bipolar transistor, there are six possible ways to apply an ESD pulse across any two of the device's terminals, while the unused device terminal remains "open" (not connected). Usually, the transistor is most susceptible to damage when ESD pulses are applied across the positive-negative (PN) junctions in a reverse



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MCA1-12G	7	3800-12000	6.2	38	10.95
MCA1-24LH	10	300-2400	6.5	40	6.45
MCA1-42LH	10	1000-4200	6.0	38	7.45
MCA1-60LH	10	1700-6000	6.3	30	8.45
MCA1-80LH	10	2800-8000	5.9	35	9.95
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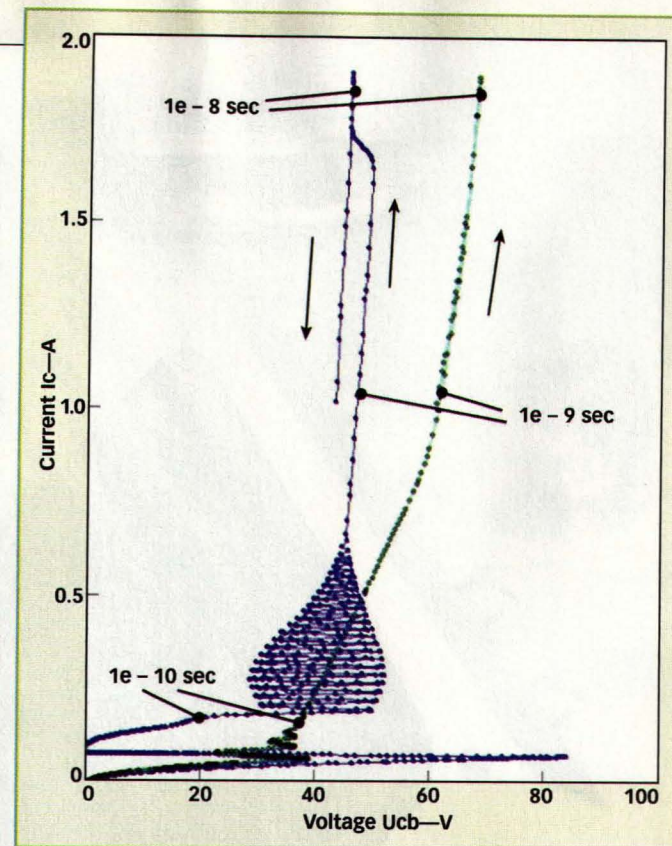
direction—e.g., with the polarity that causes a reverse-bias condition at a given junction. While dependent on specific semiconductor process technology, the collector-base junction is usually the weak link in an RF transistor. If the ESD-induced current surge is high enough, all three regions of the bipolar transistor are flooded with free carriers (electrons in the case of an NPN transistor).

During an ESD event, the base-collector space-charge is driven down into the highly doped substrate or (buried layer in RF ICs).¹ Nearly all of the transistor's voltage drops over the collector-substrate boundary, yielding increased field strength in this region (the density of free electrons in the collector region has surpassed the doping density). Since the free electron charge in the collector must be compensated by a counter charge, the only region where it can be built up is in the highly doped substrate (or buried layer).² If this field reaches the internal breakdown field strength of approximately 3×10^5 V/cm in the case of silicon, massive impact ionization occurs. More free carriers are generated (electrons and holes) and a runaway process takes place, with external voltage breakdown. This effect is called "second snapback" in ref. 1, after the V_{CEO} snapback effect.

Most of the energy contained in the ESD pulse is released at the site of the highest field strength which increases the local device temperature. This in turn increases the number of free carriers due to the intrinsic conductivity mechanism. The process continues its downward spiral via a positive feedback mechanism and as a consequence the current tends to focus onto an ever smaller spot with subsequent melting and burnout of silicon material.

To some extent, the addition of a distributed series resistance to the current path can help avoid the concentration of ESD-induced surge current.³

The series resistance forces an even distribution of surge current, and helps avoid the subsequent destructive mechanism. Careful design of a transistor cell can also help avoid such destruc-



3. These simulated I-V curves compare a conventional transistor design (blue) with an improved design (green). The simulation assumed a capacitor charges to 3000 V and discharged.

tive effects. For example, any crystal defect, any sharp edge, any abrupt corner may cause a resulting increase in localized electric field strength; such defects should be avoided.

A straightforward way to reduce ESD-induced fields is by choosing a lower doping density in the substrate in order to distribute counter charges more deeply into the substrate. Unfortunately, this approach affects the substrate resistance (and RF performance). A better way is to insert a buffer layer between the substrate and the active collector region.⁵ The dopant concentration of this buffer region must be higher than the active collector region, but lower than that of the substrate; still, it must be high enough for the buffer to serve as a substrate under normal operation (Fig. 1). This design approach was employed in the BFP460 to boost ESD tolerance from 300 to 1500 V (for a packaged device with $64\text{-}\mu\text{m}^2$ emitter area).

Simulating Performance

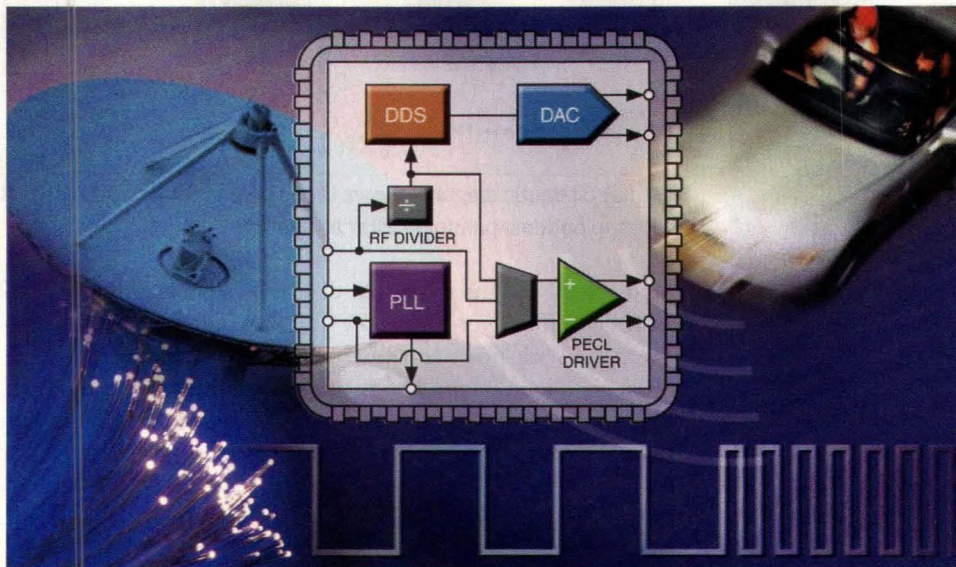
The DESSIS CAE simulator was used to learn more about ESD mechanisms. The process simulator DIOS was applied to two configurations (with and without a buffer layer) of a basic RF transistor cell as a first analysis step. For

the ESD simulation, a HBM circuit was constructed around the physical model, and the capacitor discharge was calculated in the time domain. Since the base-collector path under reverse pulse load was found to be the weakest path, it was used in the analysis. The reference capacitor was loaded to 3000 V with peak current density of about $12.6\text{ mA}/\mu\text{m}^2$ (Fig. 2). In the conventional transistor, a zone of extremely high field is generated at the collector-substrate boundary while the field remains much lower in the improved design as a result of the buffer zone. This is due to the fact that the compensating charge for the free electrons of the ESD current is distributed more deeply. A high-strength electric field is also generated around the inner base contact since this is the site of highest current density. Experimental analysis of failed devices in most cases showed melting of silicon at this location.

The current-voltage (I-V) curves of Fig. 3 display the action of the buffer layer. The curves are based on several time steps, with arrows and marks indicating the time flow. The oscillations at the beginning are caused by subsequent ignition of avalanche and voltage breakdown due to the generated free carriers but play

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MSD-3800206	2.2-2.3	44.0	0.5	10.0
MSH-4311304-DI	3.4-4.2	23.0	1.5	13.0
MSH-4421303-DI	4.4-5.0	27.0	1.1	15.0
MSH-5422102-DI	6.4-7.2	25.0	1.5	8.0
MSH-6331301-DI	8.0-9.5	23.0	2.0	12.0
MSH-6411703	9.4-10.5	30.0	1.8	32.0
MSH-7301201-DI	12.7-13.2	20.0	2.0	10.0
MSH-7321201	16.0-18.0	20.0	2.0	10.0

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MSD-3498602	.02-3.0	30.0	30.0	10.0
MSH-4384301-DI	1.0-4.0	22.0	15.0	5.0
MSH-4572502-DI	2.0-6.0	33.0	23.0	2.8
MSH-5452304	4.0-8.0	29.0	15.0	3.0
MSH-7486403	6.0-18.0	29.0	20.0	6.0
MSH-7464401	8.0-18.0	25.0	18.0	5.0
MSH-9344202	18.0-26.5	20.0	7.0	5.0

HIGH POWER AMPLIFIERS

Model Number	Freq. GHz	Gain dB, min	P1dB dBm, max	Amps @12VDC
MSD-2597601	.02-2.0	33.0	30.0	.90
MSD-3488601	.05-3.0	30.0	30.0	1.0
MSD-2654601	1.0-2.0	40.0	30.0	.80
MSH-4426602	3.7-4.2	25.0	30.0	1.0
MSH-5556603	4.0-8.0	35.0	30.0	1.0
MSH-6543603	8.0-12.0	34.0	30.0	1.1
MSH-7406601	12.7-13.2	30.0	30.0	1.2
MSH-4525701	3.7-4.2	35.0	33.0	2.0
MSH-5555701	4.0-8.0	32.0	33.0	2.0
MSH-5515701	5.9-6.4	35.0	33.0	2.0
MSH-6545701	8.0-12.0	33.0	33.0	2.0
MSH-4327702	3.7-4.2	24.0	34.7	2.0
MSH-4527702	5.3-5.9	34.0	34.7	2.0
MSH-6317701	7.7-8.5	24.0	34.7	1.8
MSH-6517702	9.0-10.0	34.0	34.7	2.0
MSH-4528704	5.3-5.9	33.0	37.0	3.2
MSH-5617801	5.9-6.4	38.0	37.0	3.6
MSH-6617801	7.7-8.5	39.0	37.0	3.6
MSH-6417802	9.0-10.0	29.0	37.0	4.4
MSH-7407801	12.7-13.5	30.0	37.0	4.8
MSH-4427902	3.7-4.2	30.0	40.0	7.0
MSH-4627903	5.2-5.8	26.0	40.0	7.0
MSH-5617902	5.9-6.4	40.0	40.0	7.0
MSH-6607801	9.5-10.5	38.0	40.0	10.0
MSH-7507902	12.7-13.2	35.0	40.0	10.5

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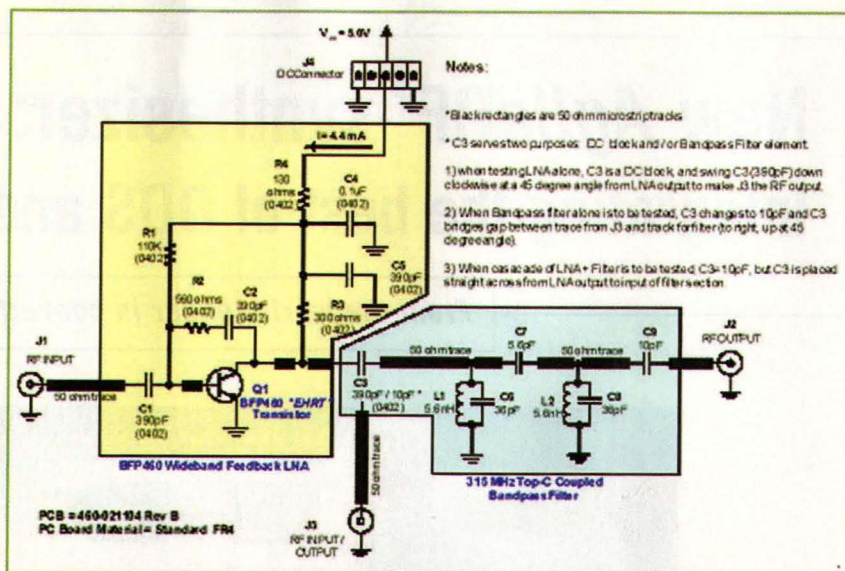
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4. This schematic diagram shows the feedback LNA based on the BFP460, along with the optional bandpass filter at right.

no role in the ESD analysis. The device with the buffer layer has an I-V characteristic with positive slope: if the avalanche should "burn" hotter at one spot, a higher voltage would be required for it. Since the voltage is fixed and the same for any spot, however, current crowding is prohibited.

The transfer of production of all discrete RF transistors into Infineon's new self-aligned double poly process also offered the opportunity to produce the new BFP460 design. In this new process, the emitter is formed by depositing an n-poly layer, rather than by implanting arsenic dopant for the emitter in the older processes. The new approach provides tighter control of production process parameters and supports high-volume runs of transistors within narrow ranges of parameter distributions. For example, DC current gain (h_{FE}) of planar RF transistors, which tends to normally scatter over a wide range, can be controlled within a narrow window of 100 to 150 with high yields in BFP460 production.

The BFP460 was used in a wideband feedback LNA for UHF (Fig. 4), although the ESD-hardened transistor is suitable for a wide range of applications. This particular LNA was used to boost the sensitivity and range of receiver RF ICs for RKE and TPMS applications at 315 and 434 MHz. The LNA requires only nine components,

including the BFP460 transistor. For reduced cost, no chip coils (inductors) are used, just resistors and capacitors. The application board includes an optional low-cost, lumped-element bandpass filter set to a center frequency of 315 MHz. The filter may be retuned for 434 MHz, and is intended to reduce the effect of out-of-band "blocking" signals on the RKE receiver chain. The application board allows testing of the LNA by itself, the filter by itself, or the cascade of the LNA and filter together.

The LNA is designed for unconditional stability and exhibits good return loss, gain, and noise figure from 300 to 1000 MHz. It can be used at the 315-, 434-, or 900-MHz ISM bands with no changes required (Table 2). Interested readers should contact the author or this magazine for a copy of the Bill of Materials (BOM) for the LNA. Application boards based on the BFP460 are available from Infineon. **MRF**

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3. J. Huber and E. Pettenpaul, United States Patent No. 5047355.
4. B. Ronan et al., "High Current Transmission Line Pulse (TLP) And ESD Characterization of A Silicon Germanium Heterojunction Bipolar Transistor With Carbon Incorporation," *IEEE 40th Annual International Reliability Physics Symposium*, Dallas, TX, pp. 175-183.
5. Diefenbeck, Herzum, Huber, Müller, German Patent WO 0205732.

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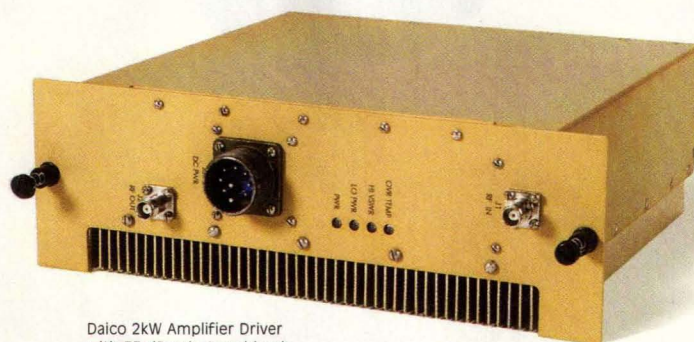
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Applying S-Parameters To Amplifier Design

This opening installment of an eight-part design series explains the concept of S-parameters and how they can be used to create basic transistor bias circuitry.

Transistor amplifier designers rely on numbers to match active devices to surrounding circuitry and to each other. They may select a transistor from a catalog, but the circuit designer has no influence over the transistor's parameters. These are set by the device's geometry, the quality of the manufacturing process, and semiconductor physics. As a result, the circuit designer must be guided by a device's

measured scattering parameters (S-parameters) to determine the circuit-element values needed to surround an active device or devices in an amplifier design. This first installment of an eight-part design series will explore S-parameters; the series itself will transform any reader into a full-fledged amplifier designer.

To the circuit designer the transistor is a two-port network described by a table of S-parameters that have been measured over the frequency domain for which it has gain. After the bias and heat sinking needs of the transistor have been satisfied, the RF design proceeds using these S-parameters. At this point it is of no consequence whether the device is a bipolar transistor, a field-effect transistor (FET), or any other device whose S-parameters indicate the prospect of gain.

S-parameters are based upon the concept of *incident* (a_i) and *exiting* (b_i) waves. Customarily the b_i waves are called *reflected* waves, but "exiting" is a better term since portions of the b_i waves actually may result from energy that passes through rather than is reflected from the network. By using a and b waves, a linear network can be characterized by a set of simultaneous equa-

tions describing the exiting waves from each port in terms of the incident waves at all of the ports. The constants that

characterize the network under these conditions are called S parameters.

For example, for a two-port network, the b wave leaving Port 1 (b_1) is the phasor sum of a wave reflected from the input port ($S_{11}a_1$) plus a wave that passed through the two-port from Port 2 ($S_{12}a_2$). That is,

$$b_1 = S_{11} a_1 + S_{12} a_2 \quad (1)$$

and

$$b_2 = S_{21} a_1 + S_{22} a_2 \quad (2)$$

where:

$$a_i = \frac{V_{il}}{\sqrt{Z_{0i}}} = I_{il} \sqrt{Z_{0i}} \quad (3)$$

$$b_i = \frac{V_{ir}}{\sqrt{Z_{0i}}} = I_{ir} \sqrt{Z_{0i}} \quad (4)$$

and the voltage at port 1, for example, is the sum of an incident voltage and a reflected voltage ($V_1 = V_{1I} + V_{1R}$). Similarly, the current at port 1 is the sum of an incident current and a reflected cur-

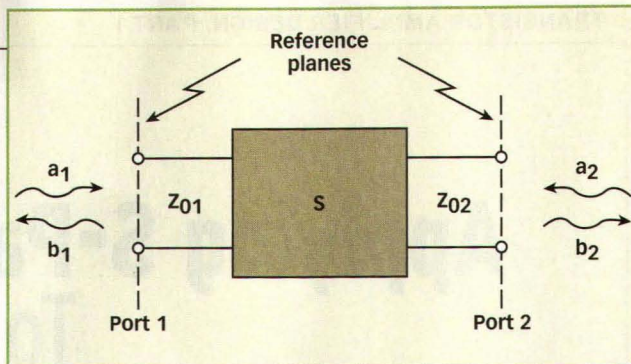
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DESIGN

rent ($I_1 = I_{1I} + I_{1R}$). The normalized incident (a_i) and reflected (b_i) waves can be measured with the aid of directional couplers with matched source and loads presented to the two-port terminals. This is equivalent to the measurement provided by a network analyzer.

This measurement simplicity underlies the advantage of the S parameters, but it introduces a complication. Whereas the alternate Z , Y , and $ABCD$



1. S -parameters derive from these defining conventions for incident (a) and reflected (b) waves.

parameters depend only upon the network being measured, the S -parameter values depend both upon the network and the characteristic impedances of the source and load used to measure it. More about the consequences of this condition will be presented later in this article series.

When the source and load impedances are the same as those used to determine the S -parameters, the magnitude of S_{21} is the ratio of the outgoing wave, b_2 , to the incoming wave, a_1 . Hence, it is equivalent to the voltage or current gain of the amplifier. Similarly, the magnitude of the square of S_{21} is equal to the power gain.

As an example, suppose we wish to design an amplifier to operate at 1 GHz with 50- Ω source and load impedances. On reviewing tables of S -parameters provided in a catalog or in an electronic file within a circuit simulator, suppose that the Motorola 2N6679A bipolar transistor is selected for the amplifier design. The table shows its S -parameters in standard format.

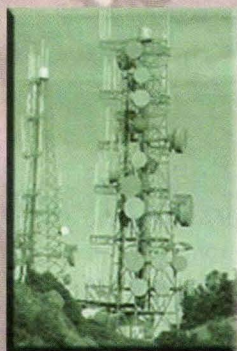
The magnitude of S_{21} can be seen as 6.6 at 1 GHz. The basic gain, without tuning, in a 50- Ω system is:

$$G = 20 \log |S_{21}| = 20 \log 6.6 = 16.4 \text{ dB (5)}$$

At this point, if this is considered satisfactory gain, it is simply a matter of designing a bias circuit.² For bias, a 20-V source should be used, since the S -parameter file indicates the performance was obtained with a 15-V bias between collector and emitter. From the transistor data, it can be seen that the performance was obtained with



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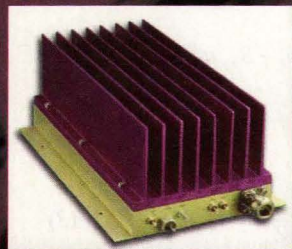
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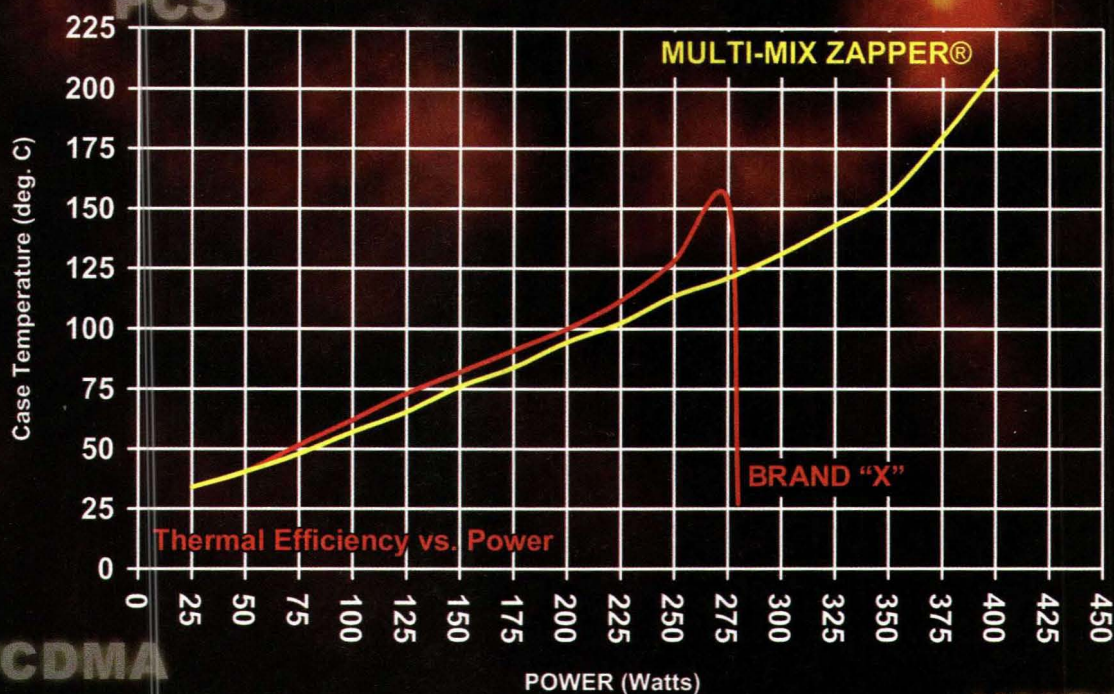
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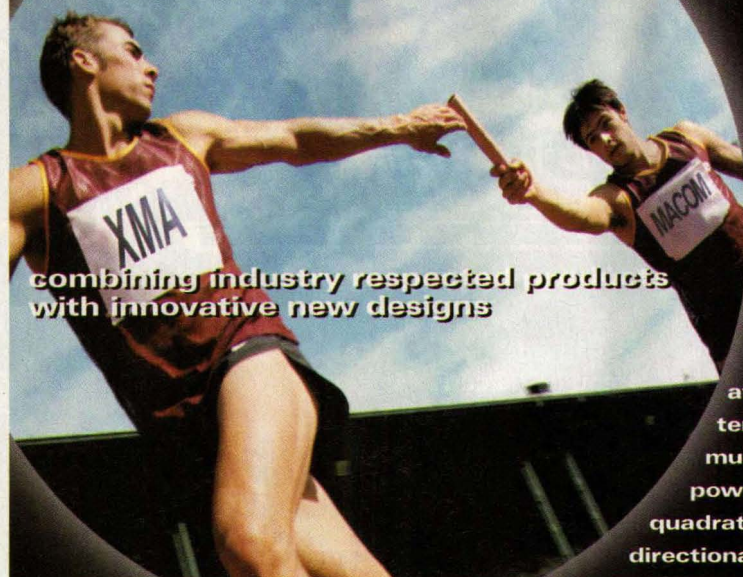
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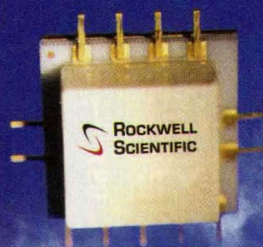
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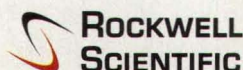
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$V_{CE} = 15 \text{ V}$ and $I_C = 25 \text{ mA}$. The DC current gain, $\beta = I_C/I_B$, is not listed in the S-parameter file, but on contacting the manufacturer, suppose that at room temperature $\beta = 40$. Based on this information, the biasing network of Fig. 2 was developed.

Applying Microwaves

JACK BROWNE
Publisher/Editor

Joseph F. White is well known in the microwave industry as an instructor and lecturer. After having received a Ph. D. in electrophysics from Rensselaer Polytechnic Institute (Troy, NY), Dr. White spent 25 years in semiconductor and component engineering at M / A - C O M (Burlington, MA) where he earned several patents for microwave design and



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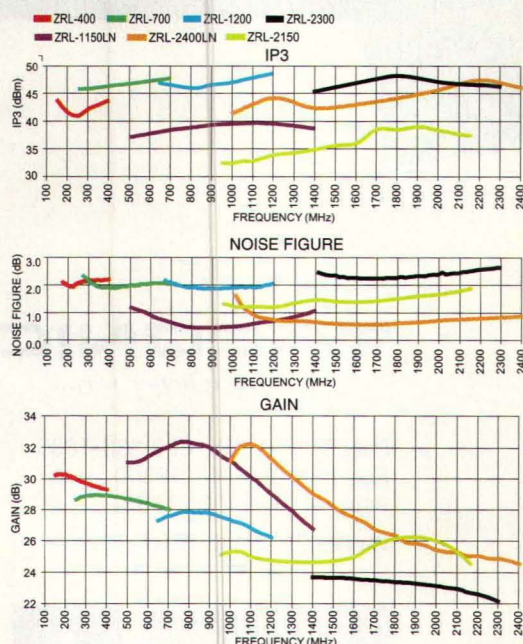
engineering. He has also received the IEEE's Microwave Theory & Techniques (MTT) Society's annual application award for "Contributions to Phased Array Antennas."

Upon leaving M/A-COM, Dr. White edited the *Microwave Journal* magazine and then founded his own publication, *Applied Microwave* magazine (later to be renamed *Applied Microwave & Wireless* magazine). In addition to writing the recently published *High Frequency Techniques* for John Wiley & Sons (Hoboken, NJ, 2004), Dr. White, who is a lifetime fellow of the IEEE, also authored *Microwave Semiconductor Engineering*, a textbook in its third printing since 1977, and now published by Noble Publications (Norcross, GA). This article series is excerpted from his new book as well as the one-week technical course that he teaches, entitled "Wireless Engineering."



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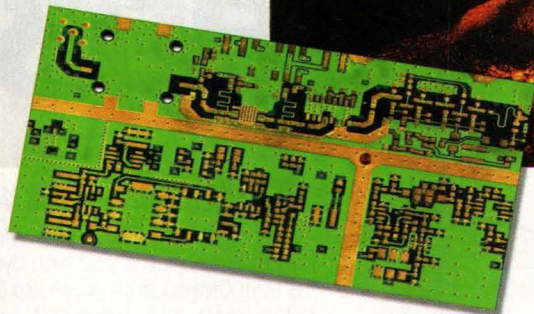
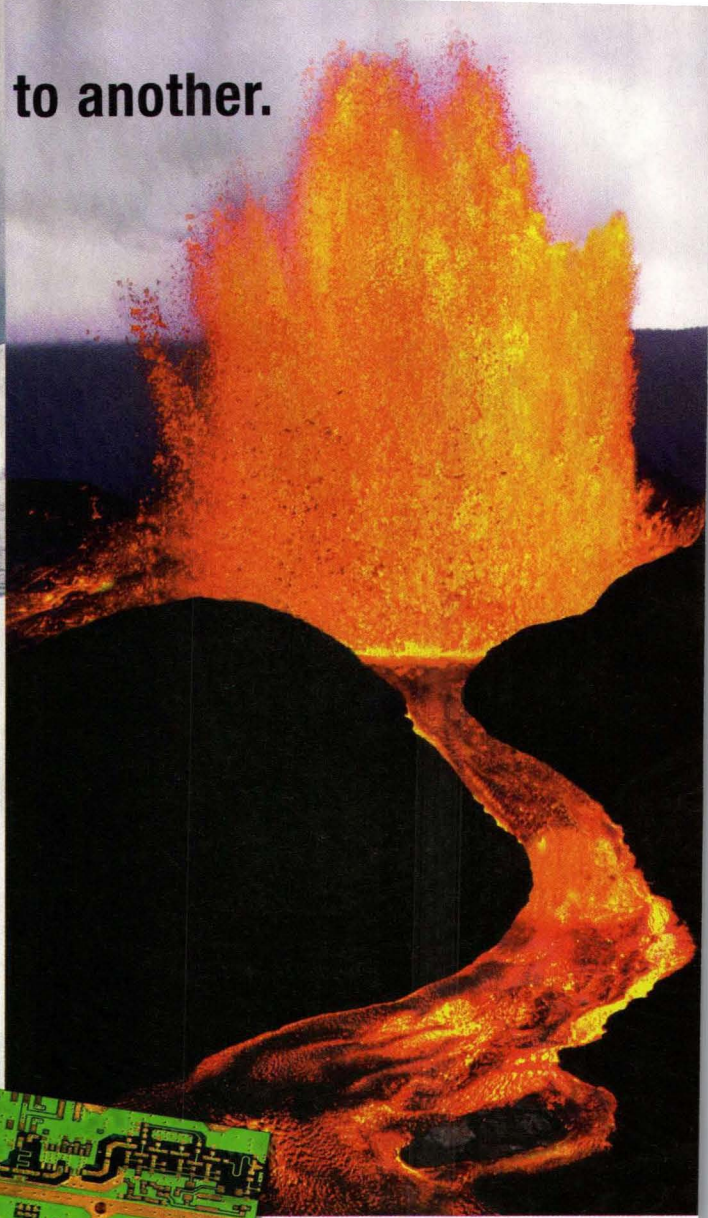
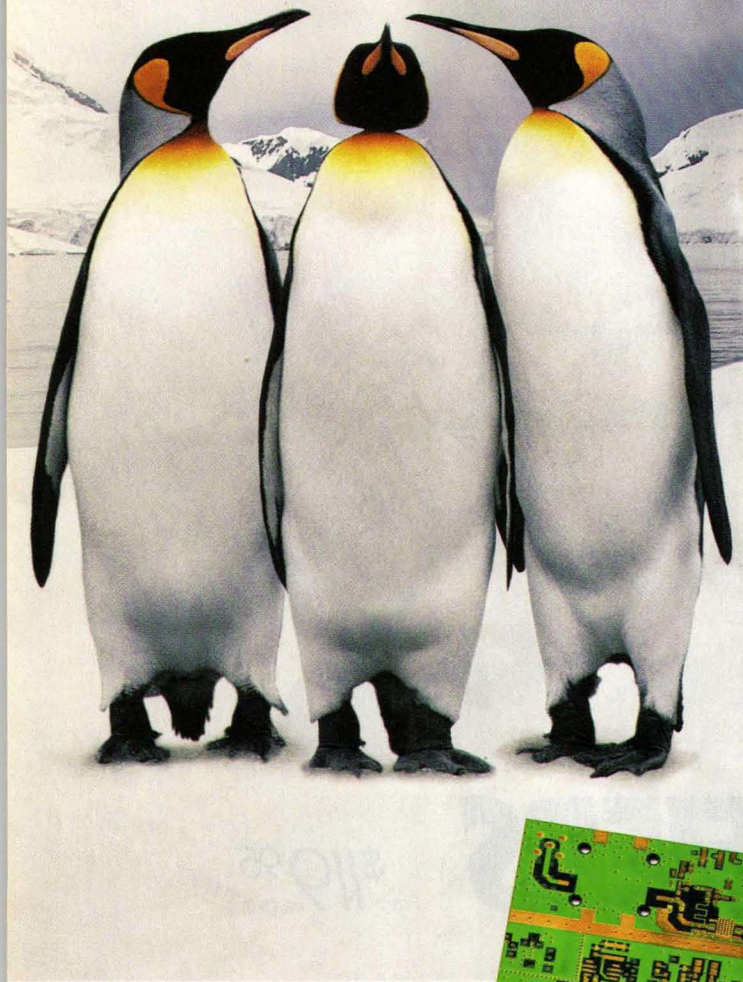
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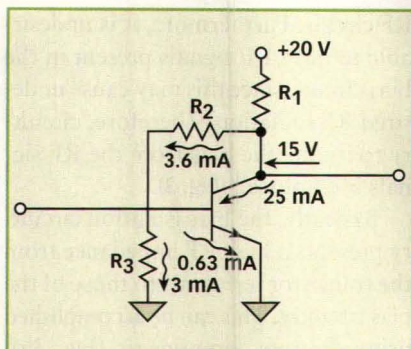
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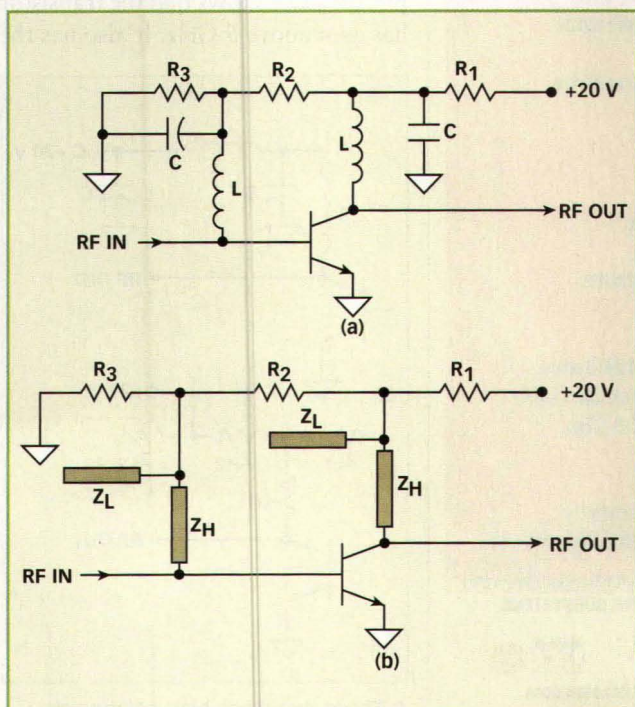
2. This simple single-stage bias network can be used to power the 2N6679A transistor from Motorola.

silicon NPN, the base-emitter junction behaves as a silicon diode. Hence, it will have a voltage drop at turn-on of about 0.75 V. The emitter-base shunting resistor can be calculated as:

$$R_3 = \frac{0.75 \text{ V}}{3 \text{ mA}} = 250 \Omega \quad (6)$$

$$R_2 = \frac{(15 \text{ V} - 0.75 \text{ V})}{3.63 \text{ mA}} = 3925 \Omega \quad (7)$$

$$R_1 = \frac{(20 \text{ V} - 15 \text{ V})}{28.6 \text{ mA}} = 175 \Omega \quad (8)$$



3. These example circuits show the use of discrete (a) and printed (b) bias isolation components.

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Practically speaking, the closest values of standard resistors may be used. This bias circuit tends to self-compensate with temperature. As temperature increases, the base current increases for a given V_{BE} . However, this causes an increase in I_C , resulting in a larger volt-

age drop in R_1 , and thereby reducing V_{BE} .

By themselves, resistors R_2 and R_3 are large compared to the 50- Ω RF impedance level at the input. However, their parasitic elements may cause them to place an excessive load on the

RF circuit. Furthermore, it is undesirable to have RF signals present in the bias circuit, since this may cause undesired RF radiation. Therefore, circuitry to isolate the bias from the RF signals is employed (Fig. 3).

Basically, the bias isolation circuitry presents a high RF impedance from the transistor terminals to those of the bias circuitry. This can be accomplished using discrete components (Fig. 3a). For the present 1 GHz, 50- Ω amplifier example isolating elements of $L=100$ nH and $C=100$ pF might be employed. When space permits the isolating elements can be "printed" as distributed elements along with the RF circuit. The transmission lines are one-quarter wavelength long at the amplifier's RF center frequency. For the 50- Ω amplifier example, the high-impedance lines might be made $Z_H = 150 \Omega$, and the low-impedance lines $Z_L = 25 \Omega$.

Bias isolating networks are crucially important in amplifier design and should not be taken for granted in the design effort. As shall later be seen, transistors may have gain at frequencies well above the design bandwidth. In the present 1-GHz amplifier example, the table shows that the transistor has gain above 5 GHz. It also has the

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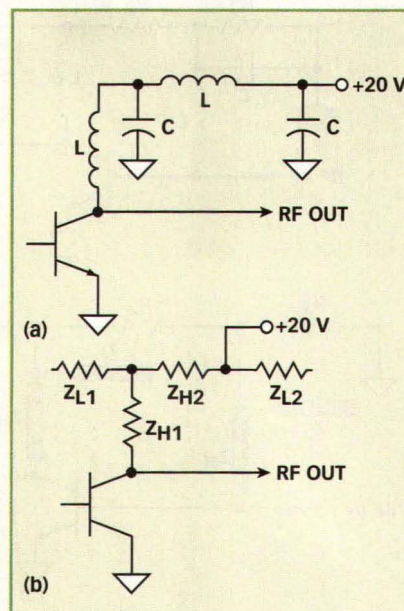


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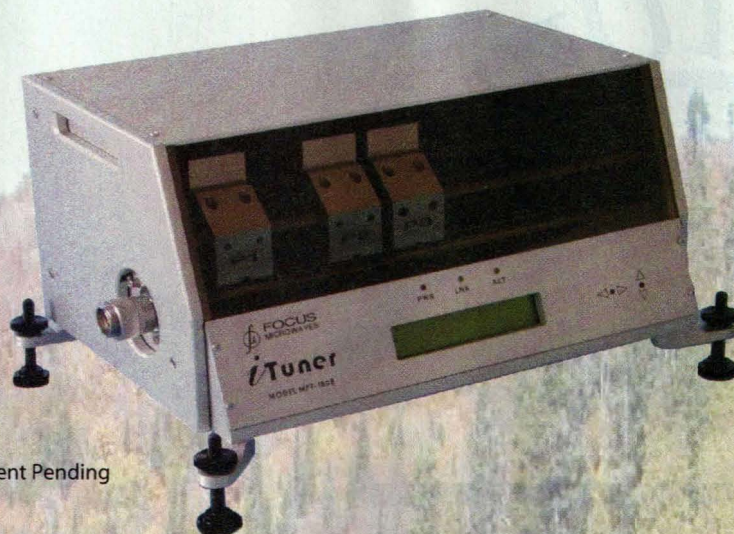
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4. These two-stage bias isolating circuits are based on discrete (a) and printed (b) circuit elements.

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*Patent Pending

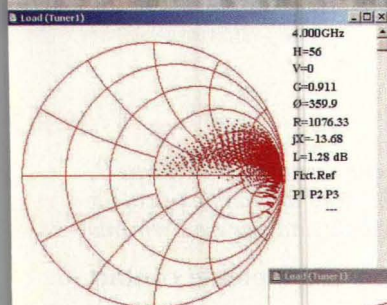
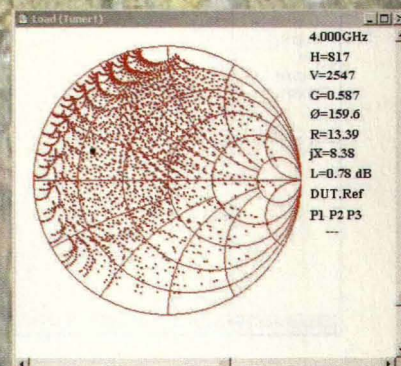


A precision electromechanical tuner for Load Pull and Noise measurements, combining:

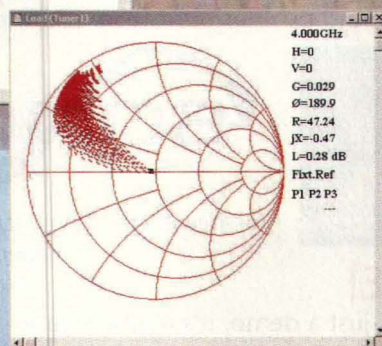
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++ Calibration time: 20 minutes / set of harmonic frequencies



Using three independent RF probes, the MPT synthesizes several million impedances at the fundamental and harmonic frequencies. This allows independent harmonic tuning, high VSWR prematching and most other crucial tuner features, all in a single unit.



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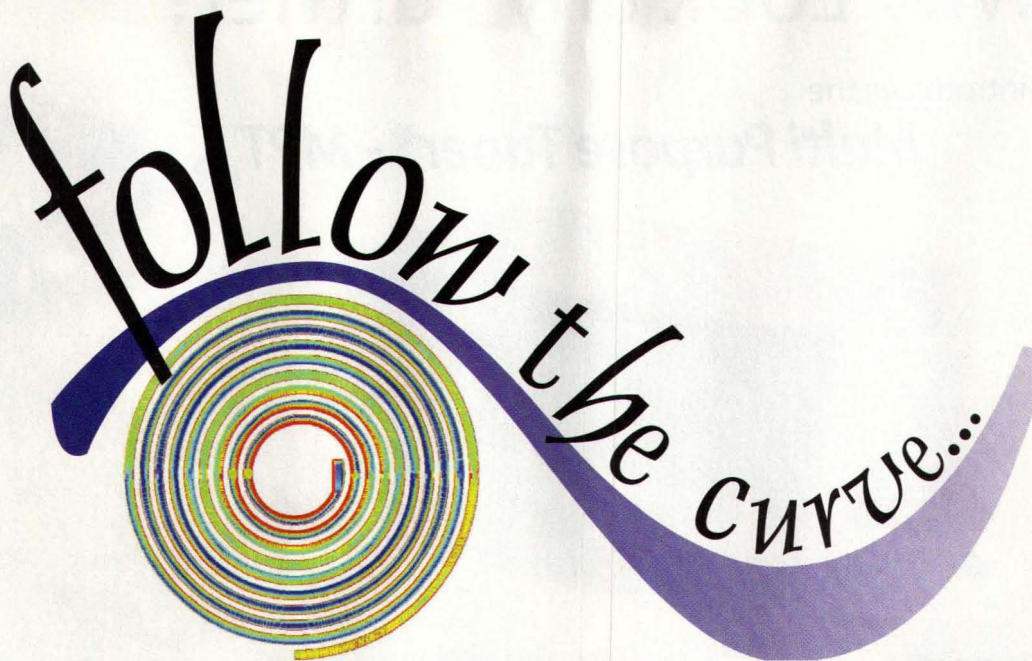
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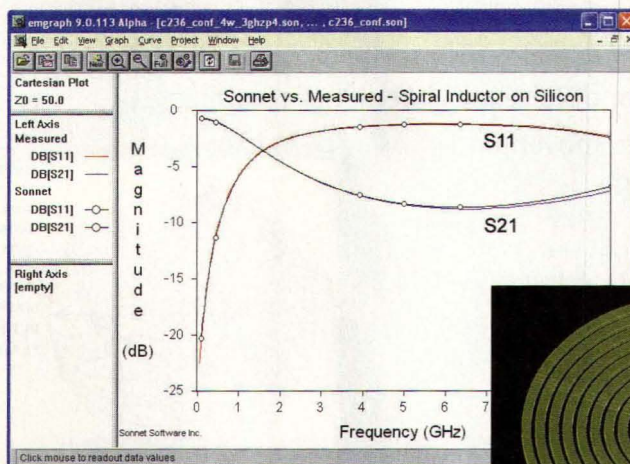


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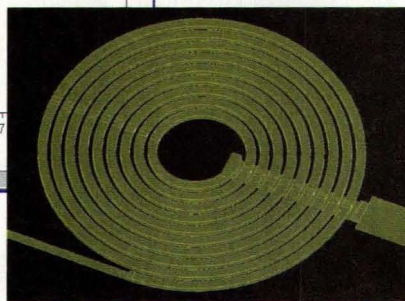
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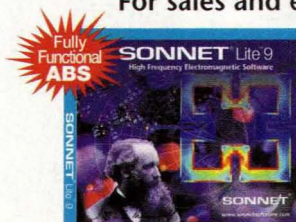


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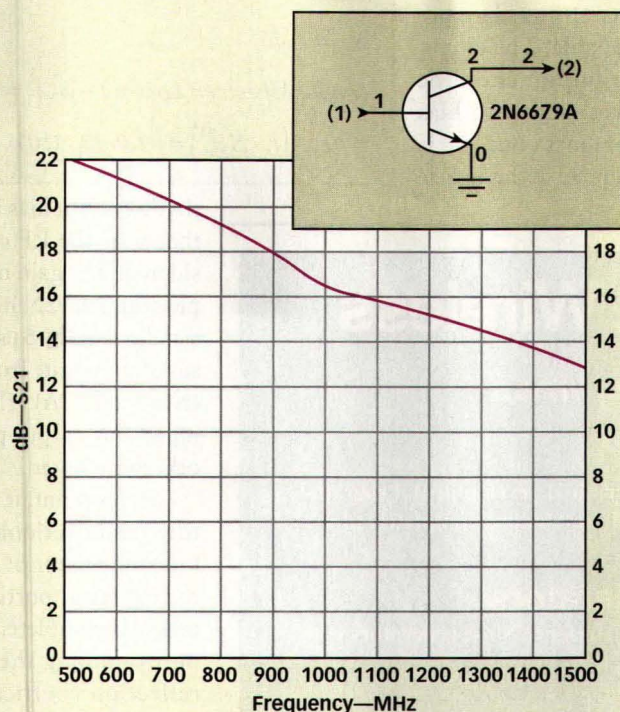
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5. This plot of S_{21} gain from 500 to 1500 MHz was generated for an amplifier based on the 2N6679A transistor using the Genesys suite of computer-simulation tools from Eagleware Corp.



potential of breaking into oscillation at any frequency for which it has gain (this potential instability will be addressed in the next installment of this article series).

The single-stage bias circuits shown in Fig. 2 have only single high-impedance

and low-impedance elements for isolation. They are shown for illustration of the bias isolating methods and are not presented as adequate designs for all applications. Where practical, multistage bias isolation is preferable (Fig. 4).

S-parameter file for the 2N667A bipolar transistor from Motorola¹

! 2N6679A.S2P

! 2N6679

! VCE = 15V; IC = 25 mA

GHz S MA R 50

! S-PARAMETER DATA

0.1	0.60	-76	38.6	141	0.01	55	0.83	-20
0.5	0.67	-158	12.7	95	0.02	40	0.50	-27
1.0	0.68	-178	6.6	77	0.03	53	0.46	-32
1.5	0.68	170	4.4	64	0.04	54	0.47	-41
2.0	0.69	162	3.4	54	0.05	54	0.47	-50
2.5	0.69	154	2.7	42	0.06	55	0.49	-59
3.0	0.69	146	1.3	31	0.07	55	0.53	-70
3.5	0.69	138	1.9	21	0.08	54	0.55	-79
4.0	0.69	131	1.7	11	0.09	51	0.57	-89
4.5	0.69	123	1.5	1	0.10	49	0.59	-97

From left to right, the columns show frequency (in GHz), S_{11} , S_{21} , S_{12} , and S_{22} , with each parameter contained in two columns [the first is numeric magnitude (not dB) while the second is phase angle (deg.)].

An informal measure of the effectiveness of the distributed bias structure is to bring a screwdriver tip near the open circuit ends of the bias flags (the open-circuited ends of the low impedance line sections) while measuring the output power of the amplifier. A significant power change experienced when so probing the end of the second bias flag, Z_{L2} , indicates the bias circuit may be resonant at the wrong frequency or that more isolating stages are required.

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D3I0118	1.6-1.8	20	.40	1.25	3	\$210.00
D3I0120	1.7-2.0	20	.40	1.25	3	\$210.00
D3I0223	2.0-2.3	20	.40	1.25	3	\$210.00
D3I0240	2.0-4.0	18	.50	1.30	1	\$215.00
D3I0260	2.0-6.0	14	.80	1.50	1	\$250.00
D3I0280	2.0-8.0	10	1.50	2.00	1	\$395.00
D3I0360	3.0-6.0	19	.40	1.30	2	\$195.00
D3I0400	4.0-8.0	20	.40	1.25	3	\$185.00
D3I0612	6.0-12.4	17	.60	1.35	6	\$195.00
DM6018	6.0-18.0	14	1.00	1.50	11	\$275.00
D3I0711	7.0-11.0	20	.40	1.25	4	\$185.00
D3I0712	7.0-12.0	20	.40	1.25	4	\$205.00
D3I0718	7.0-18.0	15	1.00	1.50	5	\$225.00
D3I0812	8.0-12.4	20	.40	1.25	4	\$180.00
D3I0816	8.0-16.0	17	.60	1.35	5	\$205.00
D3I0820	8.0-20.0	15	1.00	1.45	5	\$230.00
D3I1020	10.0-20.0	16	.70	1.40	5	\$220.00
D3I1218	12.0-18.0	20	.50	1.25	5	\$180.00
D3I1826	18.0-26.5	18	.80	1.40	5	\$225.00
D3I1840	18.0-40.0	10	2.00	2.00	5*	\$1300.00
D3I2004	20.0-40.0	12	1.50	1.65	5*	\$950.00
D3I2640	26.5-40.0	14	1.00	1.50	5*	\$700.00

Circulators

Model #	Freq Range GHz	Isol Min	Insertion Loss Max	VSWR Max	Outline #	Price Per Unit
D3C0890	8-9	20	.40	1.25	8	\$235.00
D3C0116	1.4-1.6	20	.40	1.25	8	\$235.00
D3C0118	1.6-1.8	20	.40	1.25	3	\$210.00
D3C0120	1.7-2.0	20	.40	1.25	3	\$210.00
D3C0223	2.0-2.3	20	.40	1.25	3	\$210.00
D3C0240	2.0-4.0	18	.50	1.30	1	\$215.00
D3C0260	2.0-6.0	14	.80	1.50	1	\$250.00
D3C0280	2.0-8.0	10	1.50	2.00	1	\$395.00
D3C0360	3.0-6.0	19	.40	1.30	2	\$195.00
D3C0400	4.0-8.0	20	.40	1.25	3	\$185.00
D3C0612	6.0-12.4	17	.60	1.35	6	\$195.00
DMC6018	6.0-18.0	14	1.00	1.50	11	\$275.00
D3C7011	7.0-11.0	20	.40	1.25	4	\$185.00
D3C7018	7.0-18.0	15	1.00	1.50	5	\$225.00
D3C8016	8.0-16.0	17	.60	1.35	5	\$205.00
D3C8020	8.0-20.0	15	1.00	1.45	5	\$230.00
D3C1218	12.0-18.0	20	.50	1.25	5	\$180.00
D3C1826	18.0-26.5	18	.80	1.40	5	\$225.00
D3C1840	18.0-40.0	10	2.00	2.00	5*	\$1750.00
D3C2004	20.0-40.0	12	1.50	1.65	5*	\$1350.00
D3C2640	26.5-40.0	14	1.00	1.50	5*	\$900.00

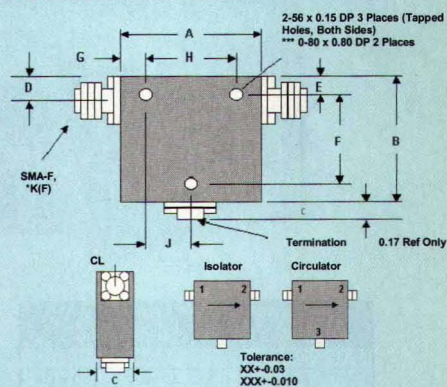
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computer-aided-engineering (CAE) circuit simulators can work with an S-parameter table to provide an analysis over frequency, interpolating the data to calculate the circuit behavior between frequencies for which actual measured

S-parameter data are available. The circuit evaluation could be performed with bias elements but it is assumed in this article

$$|S_{11}| = 0.68$$

$$\begin{aligned} \text{Input Mismatch Loss} &= 1 - |S_{11}|^2 = 1 - 0.68^2 = 0.54 \\ &= 10 \log(1 - |S_{11}|^2) = -2.7 \text{ dB} \quad (9) \end{aligned}$$

$$|S_{22}| = 0.46$$

$$\begin{aligned} \text{Output Mismatch Loss} &= 1 - |S_{22}|^2 = 1 - 0.46^2 = 0.79 \\ &= 10 \log(1 - |S_{22}|^2) = -1.0 \text{ dB} \quad (10) \end{aligned}$$

that sufficient bias isolation is achieved that only the RF circuit need be considered. The gain of the present example, using the 2N6679A transistor, was simulated in Fig. 5 using the Genesys CAE simulation suite from Eagleware Corp. (Norcross, GA). The impedance of the input and output ports is 50 Ω unless otherwise noted.

At this point, if this gain is satisfactory (and overlooking for the present time the matter of amplifier stability), the electrical portion of the amplifier design is complete. On the other hand, on examining the input and output reflection coefficients, S_{11} and S_{22} , respectively, in the table, it is apparent that a good amount of power is lost to reflection at the input and mismatch at the output. At 1 GHz,

SEE EQ. 9 IN BOX ABOVE

SEE EQ. 10 IN BOX ABOVE

These mismatch losses correspond to 46-percent power loss at the input and 21-percent power loss at the output. Therefore, by matching input and output, as much as 3.7 dB additional gain can be added, with a matched circuit at input and output as well. Next month, Part 2 of this article series will examine the means of matching the transistor to obtain this additional gain and present what is necessary to guarantee unconditional stability. **MR**

EDITOR'S NOTE

This article is excerpted with permission from the one-week industrial course, *Wireless Engineering*, that the author teaches and from *High Frequency Techniques, An Introduction to RF and Microwave Engineering*, by Joseph F. White (John Wiley & Sons, Hoboken, NJ, 2004; e-mail: www.Wiley.com).

REFERENCES

1. Genesys 7 Reference Manual, (Eagleware, Norcross, GA, 1986-2000).
2. Guillermo Gonzalez, *Microwave Transistor Amplifiers, Analysis and Design*, 2nd ed. (Prentice-Hall, Upper Saddle River, NJ, 1984), pp. 273-283.

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CNG-1700/2400	2200MHz - 2400MHz
CNG-2200/2700	2200MHz - 2700MHz
CNG-800/2700	800MHz - 2700MHz



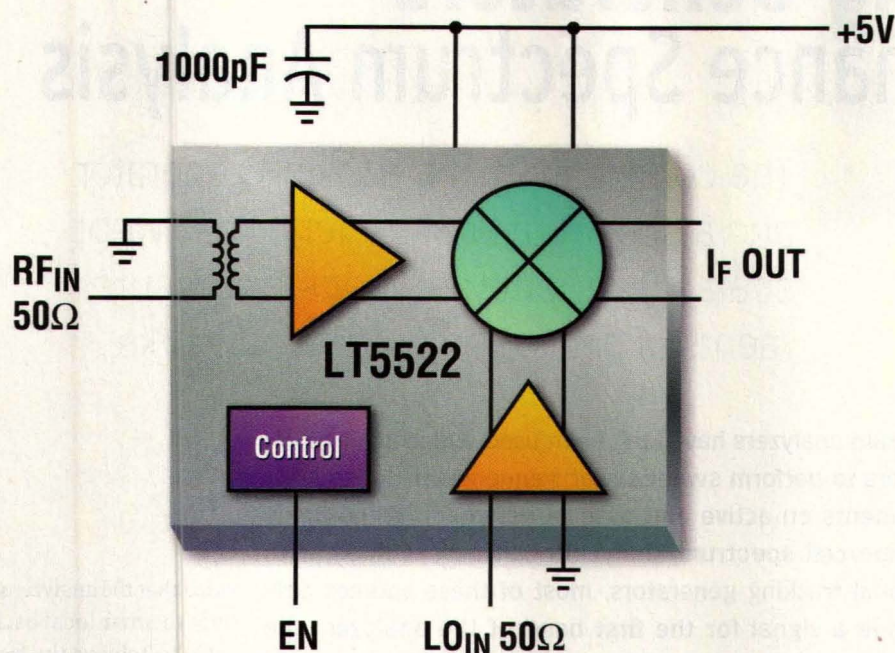
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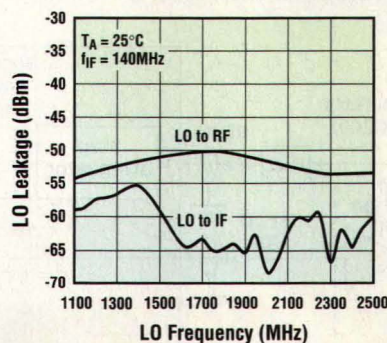
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Tracking Generators Enhance Spectrum Analysis

The combination of a tracking generator and a spectrum analyzer enables swept scalar frequency-response measurements of active and passive networks.

Spectrum analyzers have long been used with tracking generators to perform swept scalar frequency-response measurements on active and passive networks. While many commercial spectrum analyzers can be specified with optional tracking generators, most of these sources only provide a signal for the first band of the analyzer. The method that follows will also cover the first high band of

many spectrum analyzers. A method will also be presented that allows sweeping a device under test (DUT) with internal frequency conversion.

Figure 1 shows a common RF spectrum analyze architecture with the tracking generator function implemented with a mixer, amplifier, and RF signal generator set to a fixed first intermediate frequency (IF). This approach works pro-

vided that the analyzer sweeps only the first local oscillator (LO) to achieve the frequency scan. Also, the analyzer

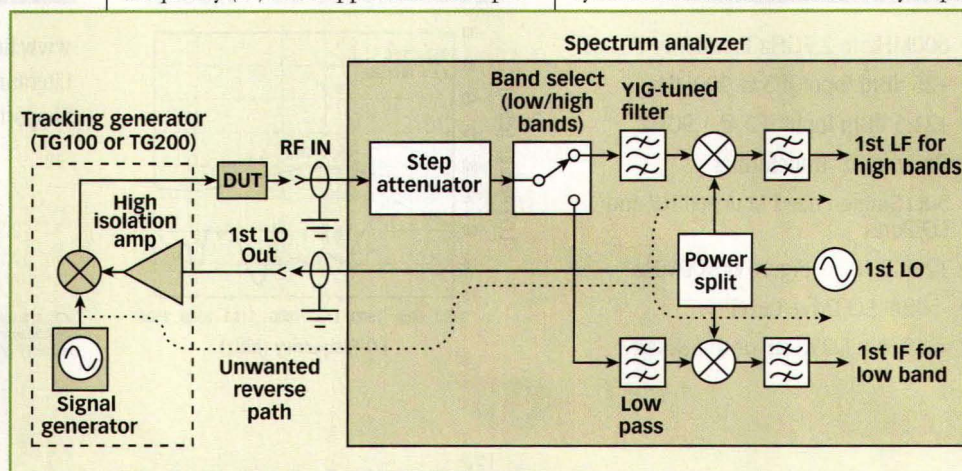
must provide a sample output of the first LO. If the analyzer's resolution-bandwidth (RBW) filters (whether analog or digital) are fixed and only the first LO is swept, then this configuration will produce the correct signal.

In this setup, the signal generator is set to the first IF of the band of interest (which can be found from the analyzer manufacturer's data or by exper-

DAN DOBERSTEIN

President

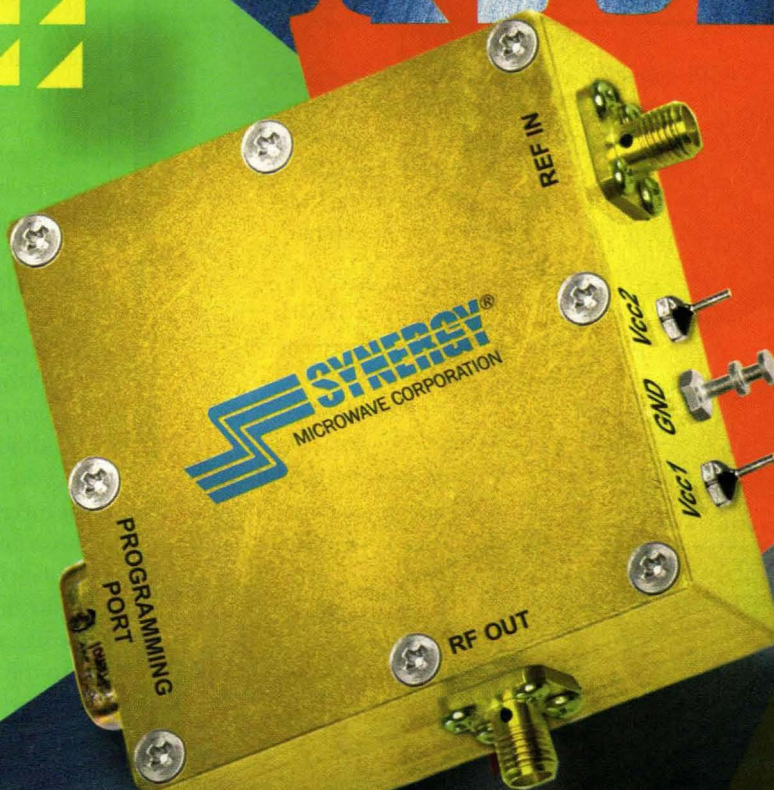
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1. This block diagram shows how a tracking generator with high-isolation amplifier can be used with a spectrum analyzer for scalar frequency-response measurements.

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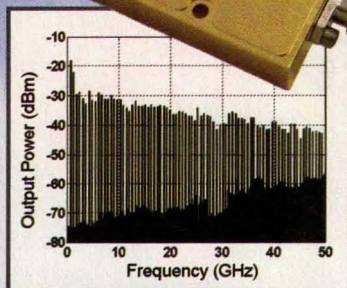
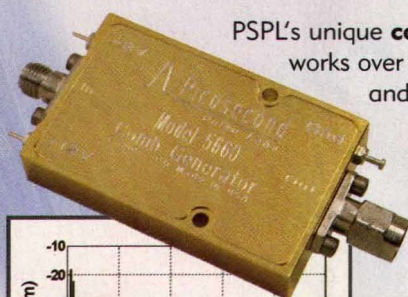


imentation). The first IF can be found by using the widest RBW filter and tuning the generator where the analyzer shows a rising noise floor. By switching to narrower RBW filters and tuning the signal generator for peak amplitude, the IF estimation can be made



2. The TG100 system integrates a wide-band mixer and isolation amplifier into a single assembly.

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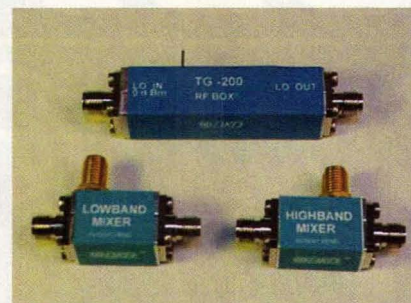
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When the analyzer's first LO signal is mixed with the signal generator's replication of the first IF signal, the output of the mixer will contain a frequency component that is exactly the RF signal the analyzer is tuned to at that point in the sweep (the tracking generator signal). The DUT is then placed between the mixer output and the analyzer's RF input. The tracking generator signal will automatically track during sweeps, providing a perfectly synchronized signal for swept scalar measurements.

Although it may be tempting to connect the analyzer's LO output directly to the mixer, this will cause a problem with most analyzers. There is usually not enough isolation in the reverse direction of the first LO output port. As a result, the signal generator's first IF signal leaks into the analyzer's first IF stage, flooding the instrument's first and subsequent IF stages and raising the noise floor.

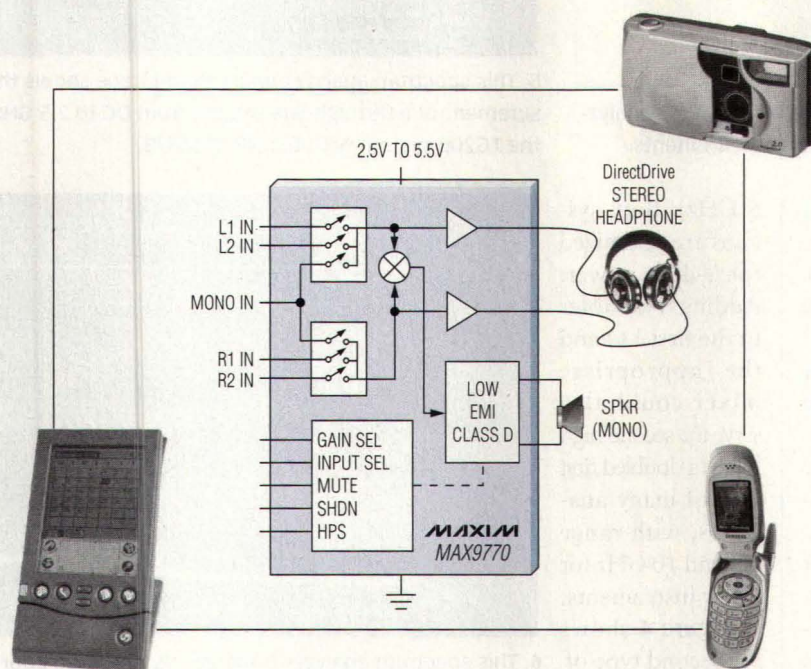
A circulator can provide increased isolation (about 20 dB) but reduce first LO power to the mixer. A better approach is a high-isolation amplifier to provide as much as 50-dB isolation to about 6



3. The TG200 system employs low- and high-band external mixers with a separate isolation-amplifier assembly.

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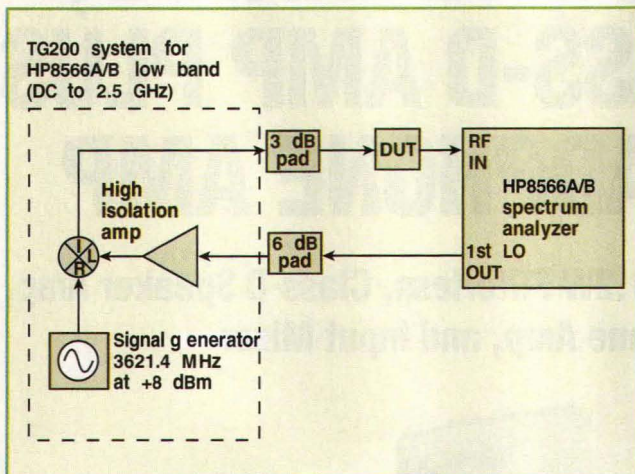
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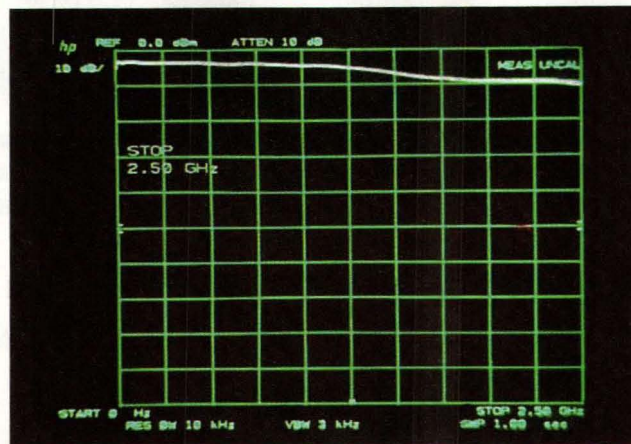
4. In this configuration, the TG200 system and HP 8566 analyzer are set up for low-band (DC to 2.5 GHz) measurements.

GHz. In addition, it allows broadband operation and good LO drive level when only low first LO level is available. The high-isolation amplifier is designed to work with 0-dBm input power.

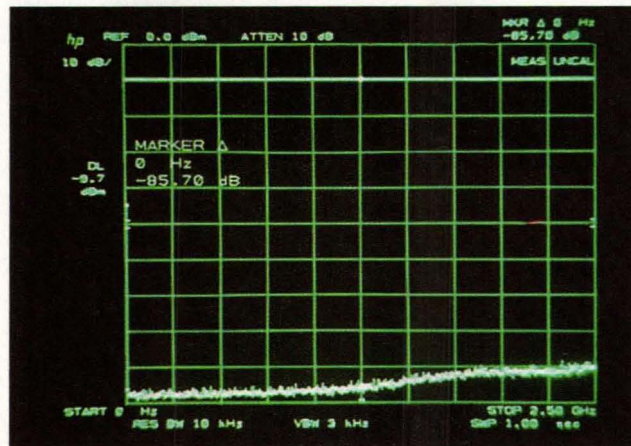
This improved approach and the configuration of Fig. 1 are the basis for two tracking-generator systems developed by DKD Instruments. In one (model TG100), the mixer and high-isolation amplifier are integrated into a single assembly (Fig. 2). In the other (model TG200), the amplifier is a separate module, allowing the use of different mixers for the low and high bands of a particular analyzer (Fig. 3). The former operates from 500 kHz to 2.6 GHz with a first high-band range of about 2.0 to 4.5 GHz. The latter uses one mixer for the low band (to 2.6 GHz) and one for the first high band (to

6 GHz). Both systems are optimized for 0-dBm power. Adding a doubler to the first LO and the appropriate mixer could also serve the second high band (a doubled first LO) of many analyzers, with range beyond 10 GHz for many instruments.

Figure 4 shows the second type of tracking generator system with an HP 8566A/B spectrum analyzer from Agilent Technologies (Santa Rosa, CA). The generator is set up to cover the instrument's first band (DC to 2.5 GHz).

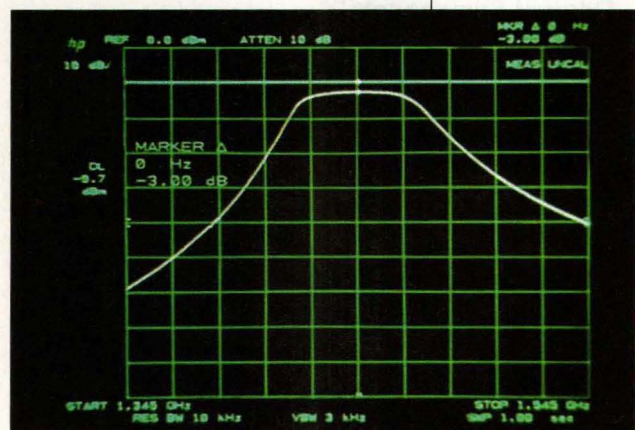


5. This spectrum-analyzer uncorrected trace shows the measurement of a through-line section from DC to 2.5 GHz using the TG200 system with the HP 8566A/B.

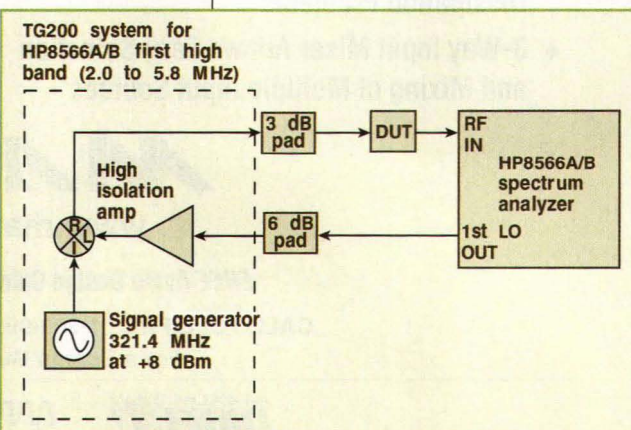


6. This spectrum-analyzer trace shows the noise floor of the TG200/8566A/B combination with 50-Ω terminations.

The instrument's first IF in the low band is 3621.4 MHz, and the signal generator is set to this frequency at a level of about +6 dBm. In this configura-



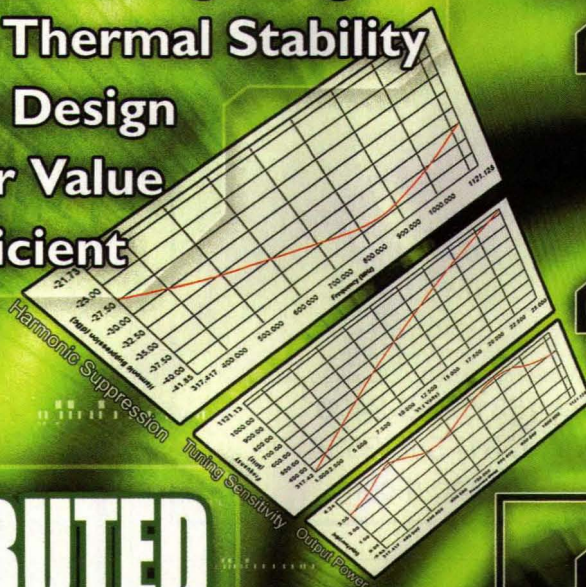
7. This trace shows the scalar frequency-response plot of a bandpass filter measured from 1.345 to 1.545 GHz.



8. In this configuration, the TG200 system and HP 8566 analyzer are set up for first high-band (2.0 to 5.8 GHz) measurements.

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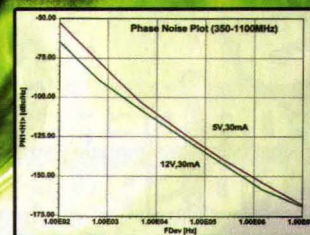
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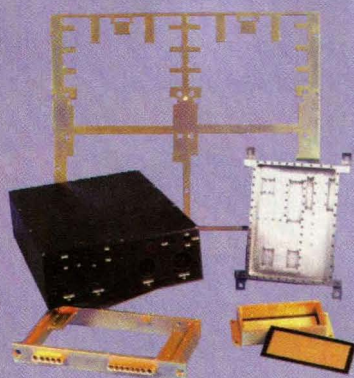
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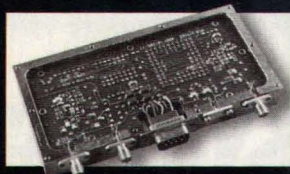
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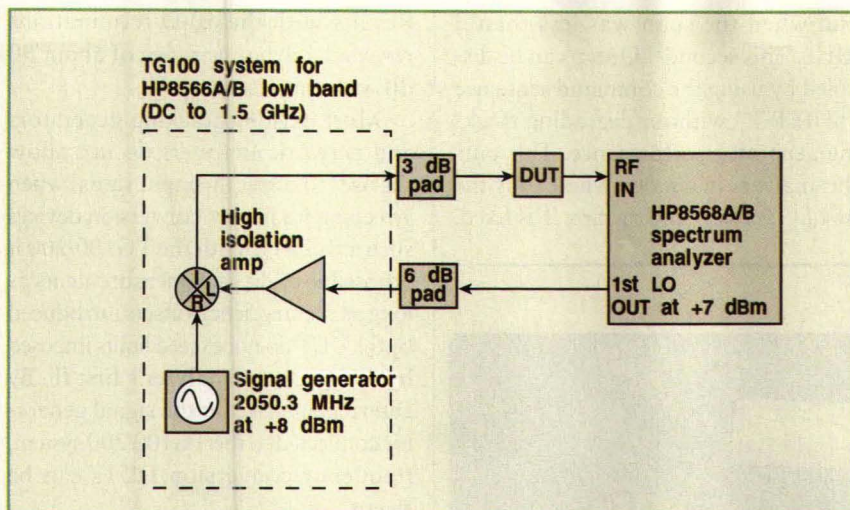
tion, the signal generator is fed to the R-port of the mixer, the first LO sample to the L-port, and the I-port contains the tracking-generator output signal as the difference product. The sum product will also be incident on the DUT input but is at $2(3621.4 \text{ MHz}) = 7242.8 \text{ MHz}$ or higher. The 3-dB pad on the I-port improves the VSWR that the DUT sees looking back toward the tracking generator. The 6-dB pad lowers the LO signal from the HP 8566 (nominally +8 dBm) to a more optimum 0 dBm for the tracking generator systems.

The test setup was used to measure a through transmission line as the DUT from DC to 2.5 GHz (Fig. 5). The uncorrected plot shows a roll off of about 7 dB from the low end to the high end with the RBW filter manually set to 3 kHz

***By entering an offset
at the signal generator
connected to the
TG100/200 system, fre-
quency-conversion
DUTs can be swept.***

and video-bandwidth (VBW) and sweep time set manually. When the through-line DUT was replaced by 50- Ω terminations on the analyzer input and tracking generator output, the noise floor could be seen in a dynamic range exceeding 80 dB (Fig. 6). The analyzer is subtracting out (in video) the roll off in the through-line response of Photo 1. The result of the video subtraction is that a through-line connection results in a flat trace. Because the correction is accomplished via video memory [VID-MEM_A- (VIDMEM_B-DL)], the noise floor rises at the high end due to the roll off in photo 1. Therefore, using a RBW of 3 kHz, signal level of +8 dBm at 3621.4 MHz, internal attenuation of 10 dB, and the 3-dB pad on the I-port, a dynamic range of approximately 80 dB is possible.

The selection of an analyzer RBW is primarily governed by the quality of



9. In this configuration, the TG100 is teamed with an HP 8568A/B analyzer for low-band (DC to 1.5 GHz) measurements.

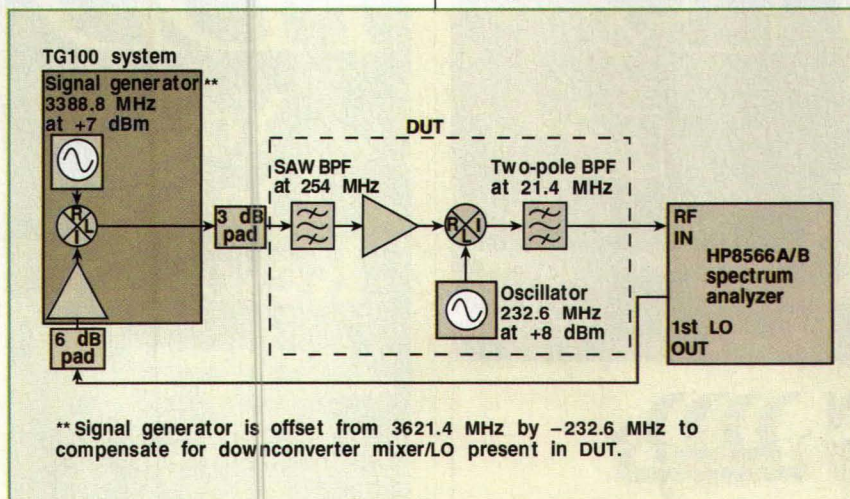
the signal generator. For an unstable source such as an unlocked cavity generator, narrowest RBW filter that can be used is about 100 kHz. A more stable source allows the use of narrower RBW filters. Of course, with a wider RBW filter, the noise floor will rise and the dynamic range will drop.

The low-band tracking-generator system was used to measure a bandpass filter with center frequency of 1445 MHz (Fig. 7). The start frequency was 1345 MHz and the stop frequency was 1545 MHz. The vertical scale is 10 dB/div, and the analyzer was set for 10-dB attenuation, 1-s sweep time, 10-kHz RBW, and 3-kHz VBW. Before the trace was taken, the reference line

was set by using video subtraction to remove the variation in tracking-generator output level.

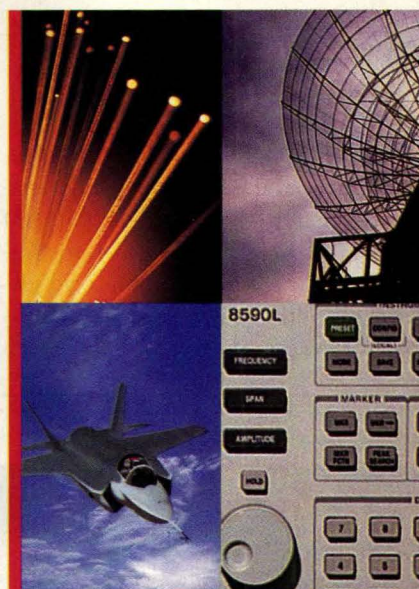
Figure 8 shows the TG200 setup for creating a tracking-generator signal for the first high band of the HP8566 spectrum analyzer. For high-band operation, the I-port of the mixer is connected to the signal generator. The analyzer's first IF for all high bands (2 to 22 GHz) is 321.4 MHz (to which the signal generator is tuned). The mixer's R-port now contains the desired tracking-generator signal and its unwanted image. The YIG tracking filter at the analyzer's input will effectively eliminate this unwanted image signal.

Figure 9 shows a TG100 system for



**Signal generator is offset from 3621.4 MHz by -232.6 MHz to compensate for downconverter mixer/LO present in DUT.

10. This setup allows the signal generator to be offset for evaluating frequency-translation devices with the TG100 system and an HP 8566A/B analyzer.



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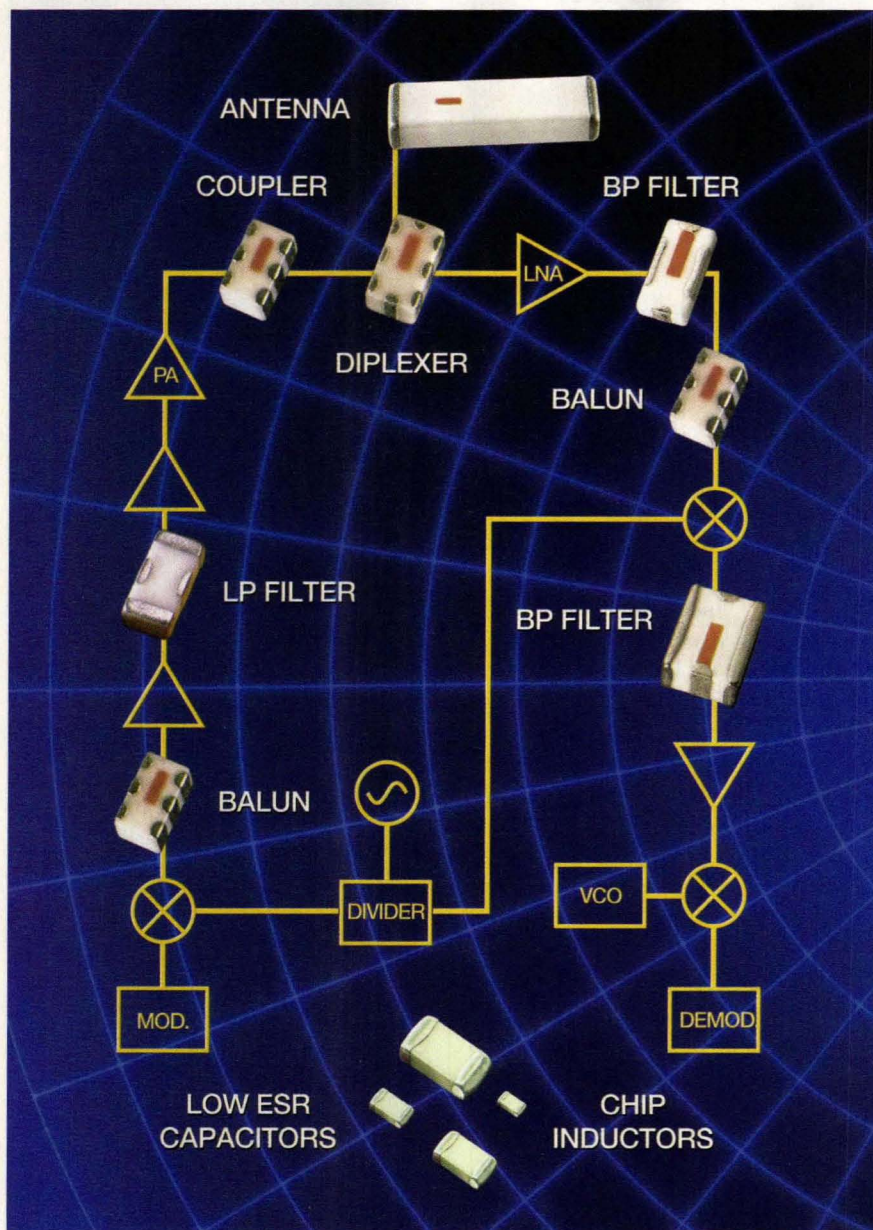
the low band of the HP 8568A/B spectrum analyzer (DC to 1.5 GHz). The analyzer's first IF is nominally at 2050.300 MHz (the frequency to which the signal generator is tuned) with fixed second LO, although the second LO shifted for certain portions of the sweep

and when the span was less than 2 MHz. This second-LO step can be disabled by using the command sequence "SHIFT T" without degrading tracking-generator performance. This puts the analyzer in a mode where only the first LO is swept and the first IF is fixed.

Results with the 50- Ω terminations revealed a dynamic range of about 90 dB with this test setup.

Most existing tracking generators and network analyzers do not allow the user to offset the input signal when sweeping frequency-conversion devices such as mixers. With the TG100/200 it is possible to do such measurements as long as the frequency offsets introduced by the DUT do not exceed limits imposed by the spectrum analyzer's first IF. By entering an offset at the signal generator connected to the TG100/200 system, frequency-conversion DUTs can be swept.

As an example, the TG100 module was used with the HP 8566 to sweep a frequency downconverter (Fig. 10). Normally, to use the TG100 with the HP8566 in its first band, the signal generator would be set to 3621.4 MHz. But since the DUT in this example has a mixer with a LO at 232.6 MHz, this must be compensated for, otherwise the tracking generator signal will be incorrect. The solution is to offset the signal generator by -232.6 MHz, resulting in an output frequency of 3388.8 MHz. This puts the tracking generator output at the correct frequency for this DUT's particular internal frequency offset. **MRF**



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Software Simulates MEMS Capacitive Switch

MICROELECTROMECHANICAL SYSTEMS (MEMS) can be thought of as miniature mechanical components fabricated with a semiconductor process. Since they share the traits of both mechanical and electrical devices, they pose a challenge for simulation programs to model. Fortunately, the APLAC MEMS Module is a computer-aided-engineering (CAE) tool developed for this purpose and supported by an application note from APLC, "Simulating a Micro-electro-mechanical Capacitive Switch using APLAC MEMS Module."

The software module is a physics-based simulation tool written for efficient and robust modeling of the electrical and mechanical characteristics of MEMS components. The program uses the equivalent-circuit approach to modeling, so that all analysis modes, including AC, DC, transient, and harmonic-balance approaches, are available. The MEMS models work in parallel in multiple physical domains, enabling simultaneous electrical, mechanical, thermal, and gas-flow simulations.

The component covered in the application note is a MEMS capacitive switch designed by

a firm associated with the cellular telephone, Nokia. The note includes details on the material properties of the MEMS device, including the length, width, and height of the switch bridge, the length of the lower electrode, the height of the isolating layer, and surface roughness.

The APLAC software module includes a component called CapacitiveSwitch which models the mechanical and electrical properties of the switch. The software, which can simulate the capacitance-voltage (C-V) characteristics of the device, can alter the bias voltage needed to change the switch state and simulate the switching speed of the structure during dynamic analysis. The software, which includes the effects of stray capacitance, divides the symmetrical switch structure into 50 sections to speed the modeling process; the note points out that in the case of an asymmetrical design, a longer modeling process is required. Copies of the four-page application note are available for free download from the company's website.

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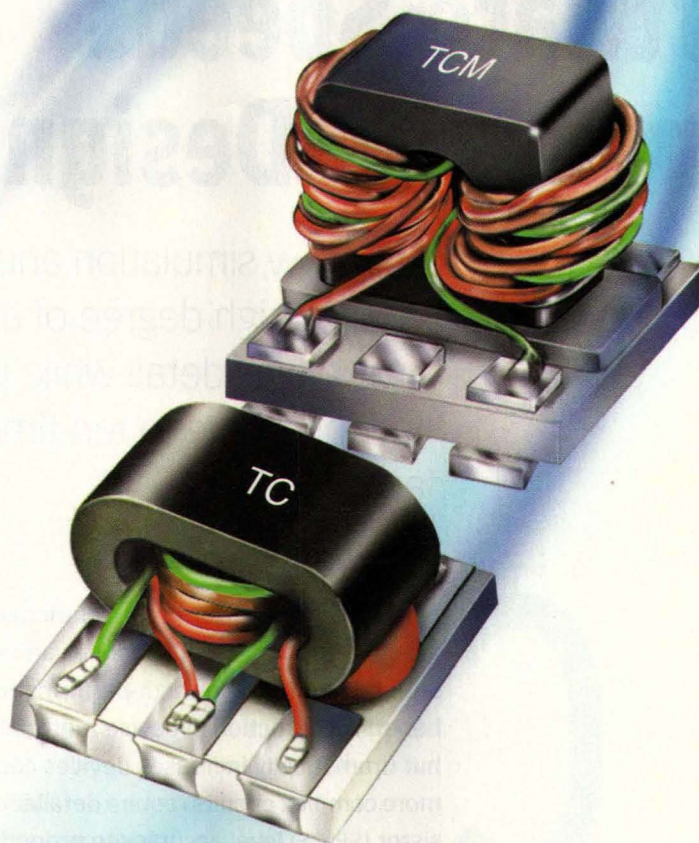
The detailed note covers information on

evaluating systems with various antenna types and accessories and shows how to measure field strength, occupied bandwidth, and channel power. It also reviews several basic types of interference, including licensed interferers, intermodulated signals, and harmonic signals.

The application note features several useful examples of field measurements with the compact analyzer, including diagnosing desensitization effects from an interferer, studying interference in cellular base stations, cellular base-station interference testing, and how to set up a directional signal survey with the analyzer. This latter measurement is made with the analyzer's own omnidirectional antenna and by selecting the proper measurement band of interference to match the location of a suspected high-power interferer. Copies of the 12-page application are available for free download from the company's website.

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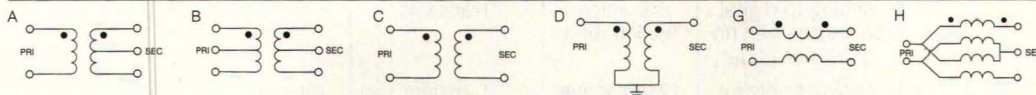
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Phase locked loop (CMOS)	1412 active 1432 total	Transient	2 days	10 h	5x
Frequency divider (GaAs)	14 active 34 total	Single-tone harmonic balance	No convergence	32 s	Infinite
Analog-to-digital converter with no parasitics (SiGe)	640 active 96,500 total	Transient	6 h	37 min	10x
Analog-to-digital converter with parasitics (SiGe)	12150 active 345600 total	Transient	Cannot parse netlist (too large)	4 h	Infinite
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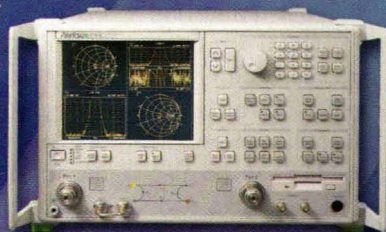
Multiport Measurements



On-Wafer Measurements



Millimeter Wave Measurements

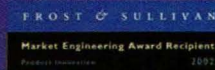


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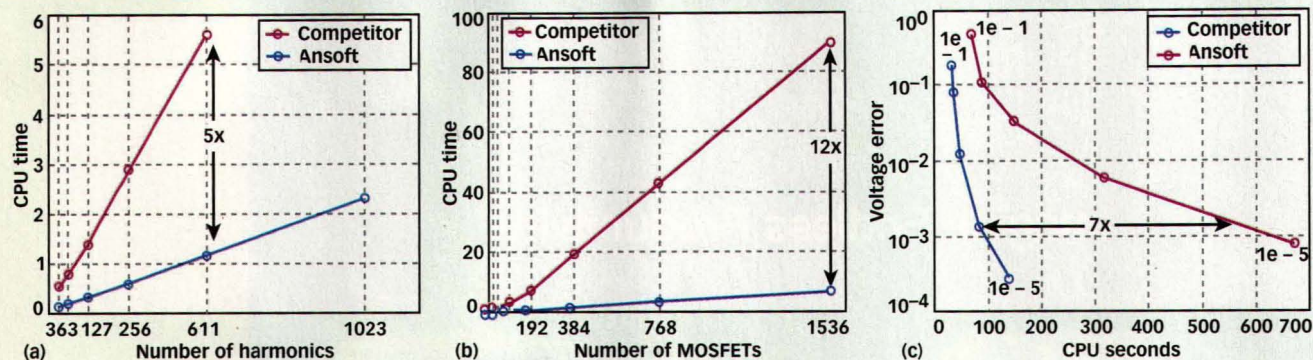
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1. Nexxim scales extremely well for large problems in both the time and frequency domains.

performance ICs. Nexxim delivers orders of magnitude improvement in simulation speed, accuracy, and capacity. Nexxim combines with Ansoft Designer and HFSS to provide a total solution for circuit design, circuit/system co-design, and post-layout verification including on-chip/embedded passives.

The table illustrates the performance advantage of Nexxim relative to current tools. As shown in Fig. 1, the software is designed for large, complex circuits: Nexxim's simulation speed advantage increases as the number of harmonics and number of transistors in the circuit increase; in other words, the larger the problem, the greater Nexxim's performance advantage. Likewise, Nexxim demonstrates a much steeper "accuracy versus simulation time" curve than existing tools; its speed advantage increases as the required solution accuracy increases.

Nexxim is easily incorporated in the

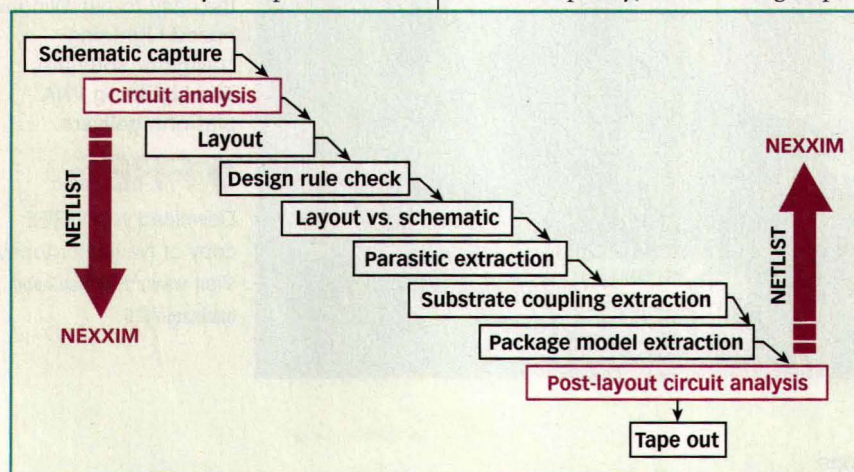
typical IC design flow to perform circuit analysis (Fig. 2). A netlist describing a circuit of interest at its pre-layout verification phase can be exported from within a design environment and imported into Nexxim for solution. The same applies for the post-layout verification phase; the extraction of local parasitics, crosstalk, interconnect delays, and substrate noise add significantly more elements to the design and augments the netlist size. This netlist can be also exported from within the design environment and imported into Nexxim for solution.

An example of the different designs tackled by Nexxim is an analog-to-digital converter (ADC), where the effects of layout parasitics, substrate coupling and packaging result in a large circuit that includes tens of thousands of transistors and passive elements to be accurately analyzed (Fig. 3). Even for a circuit of this complexity, Nexxim's large capac-

ity and fast speed provide transient solutions within minutes, allowing large parametric simulation runs to be performed within a reasonable time frame. As a result, thermal effects and process variations can be taken into account to ensure that the most optimal design architecture is used during an IC process run.

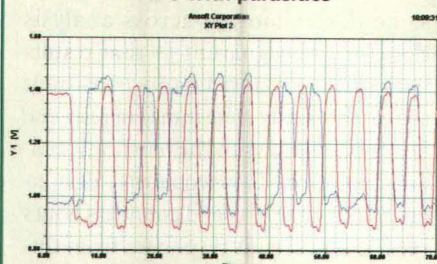
Even a small design such as a 100-MHz frequency divider with 14 active devices provides a challenge for frequency-domain simulations using current CAE tools. The output of the divider approximates a square wave, requiring the use of many harmonics for accurate characterization. By performing single-tone and multi-tone harmonic balance analyses that incorporate Krylov subspace methods, Nexxim can simulate the performance of the frequency divider quickly and accurately. Proprietary preconditioning algorithms help achieve fast convergence, and a multi-tone harmonic-balance simulation can be run with an option that uses minimal memory (often a cause for concern in circuits with many variables and harmonics).

The speed of Nexxim is apparent in the simulation of a phase-locked loop (PLL). Using current tools, about two days are needed to simulate the performance of a 430-MHz PLL circuit on a 0.15- μ m CMOS process, even if the lock voltage and frequency are set very close to their final values during simulation. Nexxim uses a new variable-time-step integration formula combined with advanced error estimation and control to decrease the solution time five times to provide greater accuracy while

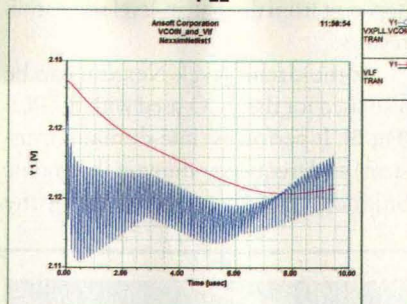


2. Nexxim is easily incorporated in the IC design flow to perform circuit analysis in the pre- and post-layout verification phases.

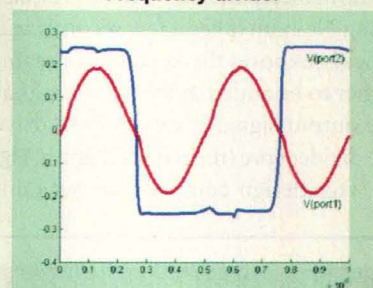
ADC with parasitics



PLL



Frequency divider



3. Nexxim performs fast transient and harmonic balance analyses for a variety of applications.

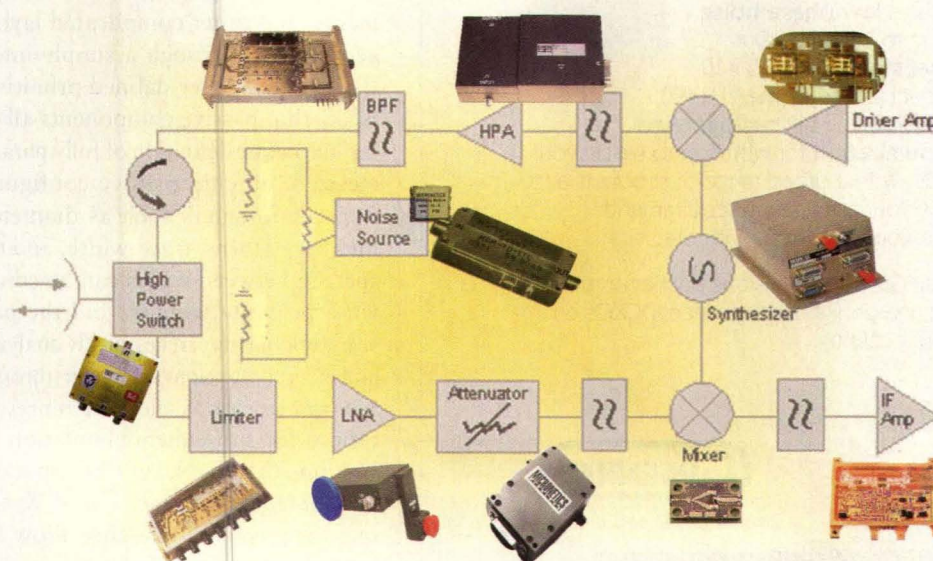
requiring fewer time points over the simulation time interval. A new sparse matrix solver specifically optimized for circuit simulation applications speeds solutions for all time points.

For high-level designs, the combination of Nexxim and Ansoft Designer allows operators to literally “toggle” between aspects of a circuit. Ansoft Designer’s system simulator can be used to size the various system components

and Nexxim can be applied to “fine-tune” the design, by performing detailed and accurate circuit-level analysis of each of the components at high simulation speed. The combination was applied to the co-design of an integer-N PLL based on a 0.25- μm CMOS process (for GSM 1800). Ansoft Designer simplifies the sizing of the prescaler residing in the PLL’s counter, while Nexxim handles the analysis of the prescaler at the circuit

level. The overall circuit contains 182 BSIM3v3.2 transistors, readily available from Nexxim’s extensive device model library. Nexxim is compatible with the golden standards in device models and netlist formats. It also provides designers with the capability of rapidly incorporating their own proprietary models; their run-time efficiency matches that of already existing, built-in models so as to not compromise simulator

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performance. Simulation of the prescaler using Nexxim takes a few seconds and quickly exposes the need for a preamplifier to be added in the design so that the output signal is sufficient to drive the divider core (the red solid line in Fig. 4). This design complication was not

apparent from the system-level simulation results.

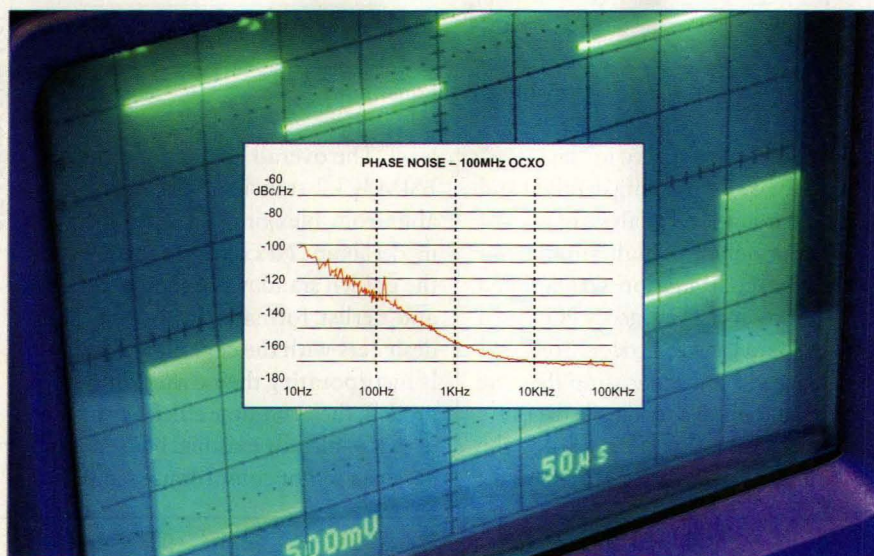
At the circuit level, Nexxim can be also used for the VCO used with the PLL (Fig. 5). It performs time-domain (transient) and frequency-domain (harmonic balance, AC) simulations using the

same circuit schematic/netlist and the same device models across analysis domains. This guarantees that results in the different domains are consistent so that the steady-state transient response is in agreement with the harmonic balance solution. Consequently, designers do not have to spend countless hours reconciling circuit responses from different simulators, running from different netlists, using different versions of device models.

After verifying the performance of the individual PLL functional blocks, the whole system is brought together into one circuit and Nexxim is used to verify the overall PLL response. Nexxim takes approximately 19 h to run a transient simulation within 20- μ s of the whole system. This is faster, more accurate and without the large waveform discontinuities present in the results of current simulations tools, which take over a week to produce a result.

Given continuing expansion of wireless applications, and with technology scaling down towards 90- and 65-nm feature sizes, accurate simulations must include noise and electromagnetic (EM) effects. Nexxim dynamically links with Ansoft's HFSS full-wave three-dimensional (3D) EM solver to obtain accurate S-parameter or equivalent-circuit models of IC packages, passive elements, and other complicated layout geometries. Through a simple interface window, user-defined primitives of on-chip passive components allow the automatic definition of fully parameterized, on-chip passive configurations. Parameters such as diameter, number of turns, trace-width, and the spacing between traces can be edited via a property window and the passive components can be quickly analyzed and incorporated into the circuit (through S-parameter or W-element representation) for subsequent simulation by Nexxim. In turn, Nexxim incorporates proprietary S-parameter and W-element implementations that allow for accurate frequency- and time-domain simulations of these frequency-domain specified elements. Nexxim provides the

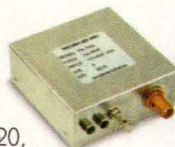
(continued on p. 104)



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Instrument Evaluates Oscillator Performance

This compact, multifunction instrument evaluates oscillator and source noise, transients, tuning linearity, and output power from 10 MHz to 7 GHz.

Oscillator and synthesizer designers struggle to measure key performance parameters for their components, such as phase noise and tuning linearity. They often rely on large racks of single-function test gear, such as power meters and power supplies, to perform difficult measurements. But the E5052A signal source analyzer from Agilent Technologies (Santa Rosa, CA) should bring a sigh of relief to these

a proprietary cross-correlation measurement method, using two measurement channels with independent

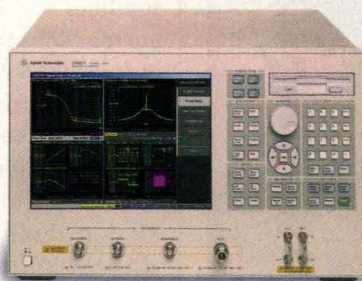
designers because this all-in-one instrument can measure the performance characteristics of nearly every type of signal source from 10 MHz to 7 GHz over a wide range of offset frequencies.

The versatile E5052A Signal Source Analyzer (**see figure**) was one of the outstanding products introduced at the recent Microwave Theory & Techniques Symposium (MTT-S) in Fort Worth, TX. The analyzer employs

reference sources and performing analysis on the two-channel signals. If the two signals are correlated and vector summed, the vector (amplitude and phase) of the two signals will be emphasized. Cross-correlation can remove the limitation imposed by the noise floor of a reference source, allowing measurements of extremely low noise levels.

The E5052A performs from 1 to 10,000 correlations to lower the noise floor, enlisting the help of digital signal processing (DSP) to derive accurate frequency and amplitude information. As with averaging, the phase-noise sensitivity improves with the number of correlations: for example, 10 correlations yields a 5-dB improvement in the noise floor improvement, while 10,000 correlations provide a 20-dB improvement in the noise floor.

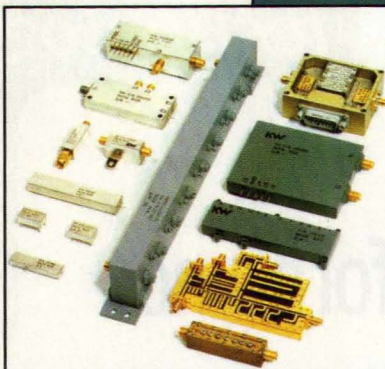
Normally, techniques like averaging and cross correlation add time to a measurement. But in the E5052A, a 100-MHz digital-to-analog con-



The E5052A Signal Source Analyzer is a versatile oscillator and synthesizer tester with carrier range of 10 MHz to 7 GHz and offset range of 1 Hz to 40 MHz.

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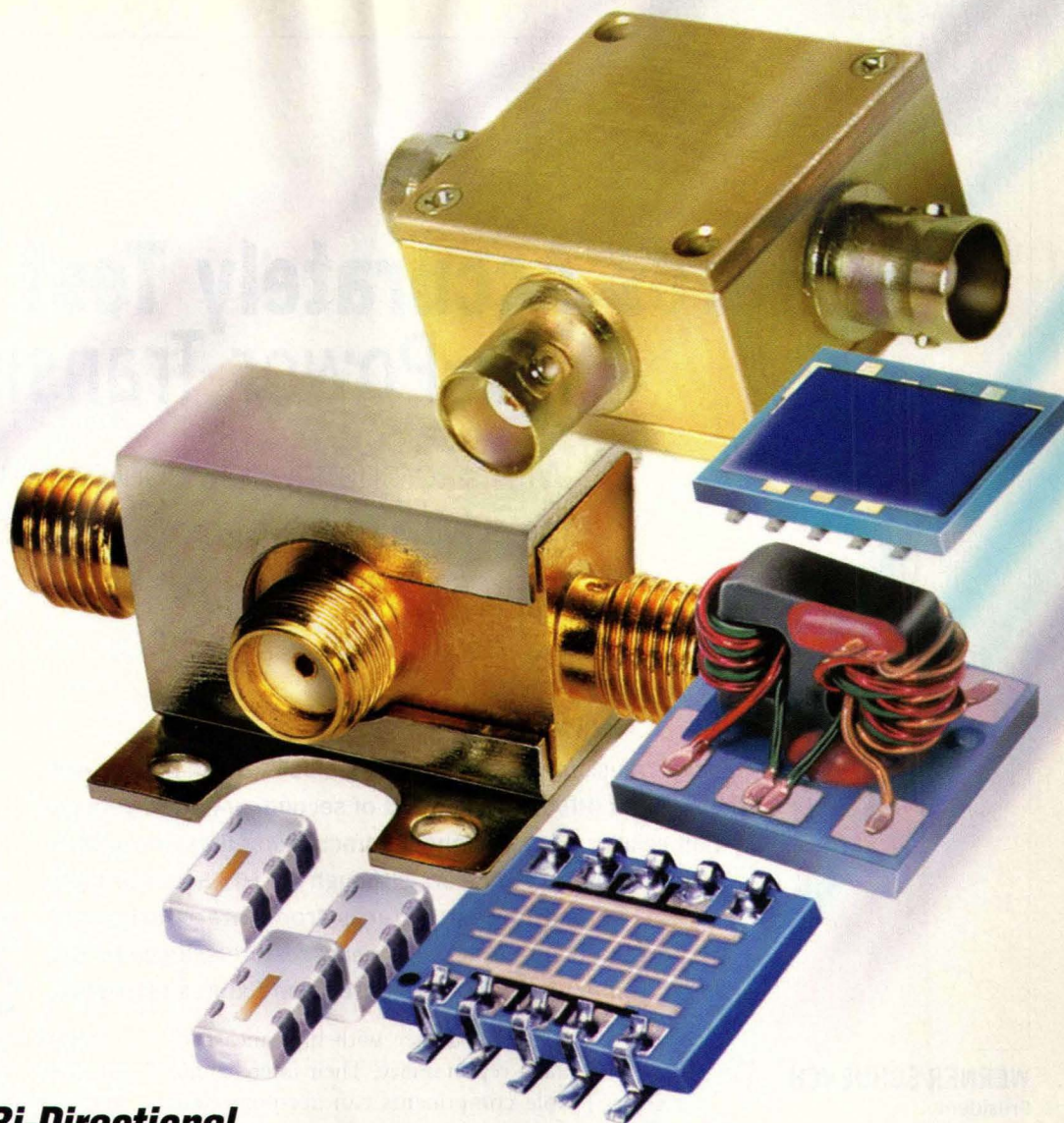
The E5052A at a glance

Carrier frequency range	10 MHz to 7 GHz (110 GHz with downconverters)
Measurement capabilities	Phase noise, transients (frequency, phase, and power versus time), power, frequency, and DC current
Phase-noise testing	
Offset frequency range	1 Hz to 40 MHz
Noise sensitivity	Less than -178 dBc/Hz
Measurement method	Two-channel cross correlation
Transient testing	
Parameters	Frequency, phase, and power versus time
Time resolution	10 ns to 160 μ s
Frequency resolution	5 Hz to 7 kHz (heterodyne mode)
Frequency transient range	1.6 to 25.6 MHz (heterodyne mode) 4.8 GHz max. (direct mode)
Pretrigger capability	-80 percent of time span or +1 s
DC testing	
Parameters	DC current (DUT power only)
DC sources	-15 to +35 VDC for control voltage, with maximum of 20 mA current 0 to +16 VDC for power voltage, with maximum of 80 mA current

verter (DAC) is used with a DSP-based stepped Fast Fourier Transform (FFT) to speed the calculations.

The instrument measures the spectral content for carrier signals of 400 MHz and greater at offset frequencies from 1 Hz to 40 MHz. For carrier signals below 400 MHz, the offset range is 1 Hz to 10 percent of the carrier frequency. The phase-noise sensitivity is typically -164 dBc/Hz offset 40 MHz from a 7-GHz carrier and -174.5 dBc/Hz offset 40 MHz from a 10-MHz carrier when putting + 5 dBm signal, and it can be extended as low as -178 dBc/Hz with the cross-correlation technique (see table). The measurement accuracy is typically ± 4 dB for offsets from 1 Hz to 1 kHz, ± 2 dB for offsets from 1 kHz to 1 MHz, and typically ± 3 dB for offsets greater than 1 MHz.

In addition to phase noise, the E5052A measures tuning linearity, output power, frequency, transients, and current consumed (see table). Its frequency range can be extended to 110 GHz by external downconverters. It offers improved capabilities compared to the company's existing source-measurement solution, the 4352S VCO/PLL Signal Test System, at a fraction of the cost and size. The E5052A includes a Windows-style operating interface, 10.7-in. thin-film-transistor (TFT) liquid-crystal-display (LCD) screen with touch-sensitive (touch-screen) surface, and programming via SCPI or Microsoft Visual Basic for Applications (VBA). Connectivity is via GPIB, USB, and Ethernet. P&A: From \$75,000; 30 days. Agilent Technologies, Test and Measurement Organization, 5301 Stevens Creek Blvd., MS 54LAK, Santa Clara, CA 95052; (800) 829 4444 ext. 7799.



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Fixtures Accurately Test High-Power Transistors

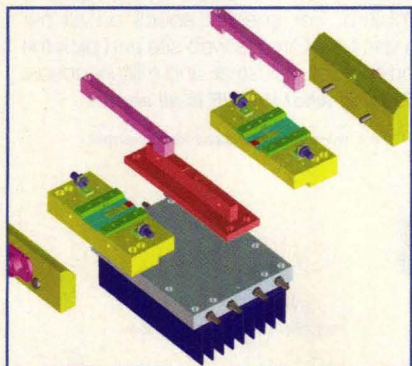
With interchangeable components to handle a wide range of devices, these fixtures address the unique needs of characterizing high-power transistors.

Power transistors are the building blocks of the high-power amplifiers (HPAs) at the heart of second- and third-generation cellular base stations. Characterizing these devices is often considered a fine art, although the HTF Series of high-power transistor test fixtures from Intercontinental Microwave (Santa Clara, CA) helps restore science to the measurement process. These precision fixtures offer good

launch. A base plate, heat sink, and through-reflect-line (TRL) calibration standards round out the configuration.

WERNER SCHUERCH President

Intercontinental Microwave, 1515 Wyatt Dr., Santa Clara, CA 95054-1586; (408) 727-1596, FAX: (408) 727-0105, e-mail: sales@icmicrowave.com, Internet: www.icmicrowave.com.



The HTF Series fixtures for high-power transistor testing have interchangeable components that make it possible to accept nearly any device and connector combination.

RF performance with high measurement repeatability. Their interchangeable components can accommodate nearly any device package and connector combination. The fixtures can be fabricated with several substrate options and connector types for power-handling capability exceeding 200 W CW for both packaged and chip (with adapters) transistors.

The HTF Series fixtures (see figure) include both 50- Ω models with broad bandwidths and prematched fixtures (such as 11 Ω) for narrowband (several hundred megahertz) testing. Users can tailor a test fixture to a device under test (DUT) by selecting different fixture component parts. Building a fixture involves selecting a midsection that is the correct width and mounting height for the DUT. Then, the launch assembly is chosen (either 50 Ω or a specific matched circuit). Pusher assemblies are also selected for the fixture input and output sides to match the width of the transistor tab. A transition is then chosen with the connector type and RF pin to match the size of the microstrip

Fixtures can be fabricated with different substrates, including soft boards, 25- and 50-mil alumina, and customer-defined substrates. The frequency coverage can be as wide as DC to 18 GHz. A series of TRL calibration standards is available based on both FR-4 and alumina for applications from DC to 4 GHz and DC to 26.5 GHz, respectively. The FR-4-based calibration standards are available matched to 50 Ω while the alumina standards can be specified to 11 or 50 Ω .

The HTF Series midsection can handle flanged or flangeless transistor package types. A special clamping mechanism ensures proper heat transfer. A heat sink created for the HTF Series can also be used, which allows fan cooling.

The HTF Series fixtures are available with a variety of different connector types, including APC-7, APC-3.5, SSMA, Type N, and 7/16 EIA connectors. Intercontinental Microwave, 1515 Wyatt Dr., Santa Clara, CA 95054-1586, (408) 727-1596, FAX: (408) 727-0105, e-mail: sales@icmicrowave.com, Internet: www.icmicrowave.com.

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5WAY	0.50-1.98
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8WAY	0.50-8.40
9WAY	0.80-4.80
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MEMS Switches Run For 100 Billion Cycles

These rugged MEMS switches offer low insertion loss, high isolation, and high linearity for a variety of commercial and military applications needing high reliability with low current consumption.

microelectromechanical systems (MEMS) technology is coming of age in terms of reliability. The RMSW200 RF MEMS single-pole, single-throw switch offered by RadantMEMS (Stow, MA), for example, has been performance tested at 10 GHz for high reliability even over 100 billion switching cycles. The switch, which is designed for applications from DC to 40 GHz, also shaves insertion loss to a bare minimum

while the on-response switching time is about 5 μ s.

Performance testing conducted on an eight-contact

compared to competing technologies, such as PIN-diode-based solid-state switches.

The company's MEMS switches are three-terminal devices that employ a cantilever beam. The switches are fabricated with an all-metal surface micromachining process on high-resistivity silicon. For environmental protection, the switches are hermetically sealed within wafer-scale packaging. A basic RadantMEMS switch configuration consists of a drain, source, gate, and beam (see figure). The beam is deflected by applying a voltage between the gate and source electrodes. The free end

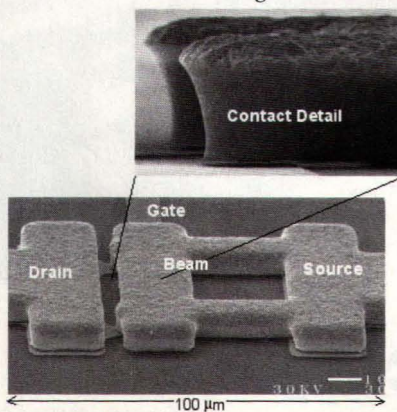
of the beam contacts the drain and completes an electrical path between the drain and the source. The company's switches are designed for actuation (gate) voltages from 40 to 120 V. At low frequencies, the on resistance has been measured at less than 1 Ω ,

MEMS switch with 0.5-W input power at 10 GHz revealed the device to be perfectly functional when the testing was stopped after 100 billion switching cycles. Both insertion loss and isolation remained stable over the life of the switch. For a switching rate of 1 kHz, the power consumption was a low 5 μ W. The company's DC-to-40-GHz model RMSW200 SPST switch is among the highest-frequency commercial MEMS switches. It features less than 0.5 dB insertion loss to 38 GHz and better than 20 dB return loss to 36 GHz. Insertion loss is typically less than 0.27 dB at 2 GHz. The isolation is 20 dB at 10 GHz and 13 dB at 40 GHz.

The model RMSW100 SPST switch is designed for use from DC to 12 GHz. It features less than 0.15 dB insertion loss at 2 GHz and more than 25 dB isolation at 2 GHz, with better than 30-dB return loss at 2 GHz. RadantMEMS, 255 Hudson Rd., Stow, MA 01775; (978) 562-3866, FAX: (978) 562-6277, e-mail: sales@radantmems.com, Internet: www.radantmems.com.

JACK BROWNE
Publisher/Editor

The MEMS switch's cantilever beam is deflected by applying a voltage between the gate and source electrodes. The free end of the beam contacts the drain and completes the electrical path between the drain and the source.



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Gali □ 21	DC-8000	14.3	12.6	4.0 27	128	40 3.5	.99
Gali □ 2	DC-8000	16.2	12.9	4.6 27	101	40 3.5	.99
Gali □ 33	DC-4000	19.3	13.4	3.9 28	110	40 4.3	.99
Gali □ S66	DC-3000	22	2.8	2.7 18	136	16 3.5	.99
Gali □ 3	DC-3000	22.4	12.5	3.5 25	127	35 3.3	.99
Gali □ 6F	DC-4000	12.1	15.8	4.5 35.5	93	50 4.8	1.29
Gali □ 4F	DC-4000	14.3	15.3	4.0 32	93	50 4.4	1.29
Gali □ 51F	DC-4000	18.0	15.9	3.5 32	78	50 4.4	1.29
Gali □ 5F	DC-4000	20.4	15.7	3.5 31.5	103	50 4.3	1.29
Gali □ 55	DC-4000	21.9	15.0	3.3 28.5	100	50 4.3	1.29
Gali □ 52	DC-2000	22.9	15.5	2.7 32	85	50 4.4	1.29
Gali □ 6	DC-4000	12.2	18.2	4.5 35.5	93	70 5.0	1.49
Gali □ 4	DC-4000	14.4	17.5	4.0 34	93	65 4.6	1.49
Gali □ 51	DC-4000	18.1	18.0	3.5 35	78	65 4.5	1.49
Gali □ 5	DC-4000	20.6	18.0	3.5 35	103	65 4.4	1.49
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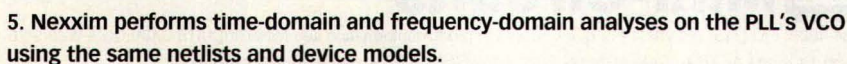
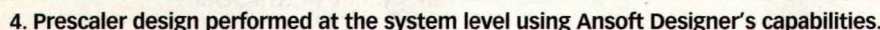


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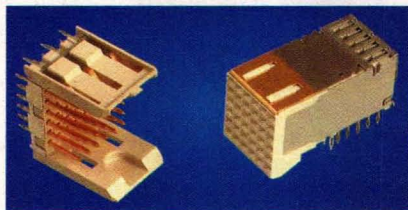
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VLF-575	DC-575	770	900	20.95
VLF-630	DC-630	830	970	20.95
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VLF-1000	DC-1000	1300	1550	19.95
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VLF-2250	DC-2250	2575	2850	19.95
VLF-5000	DC-5000	5580	6600	19.95
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VLF-6700	DC-6700	7600	8900	19.95

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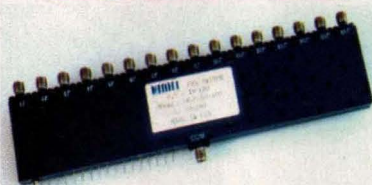
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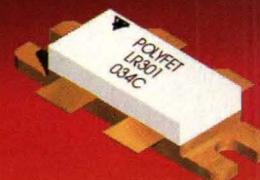
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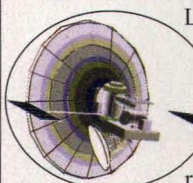
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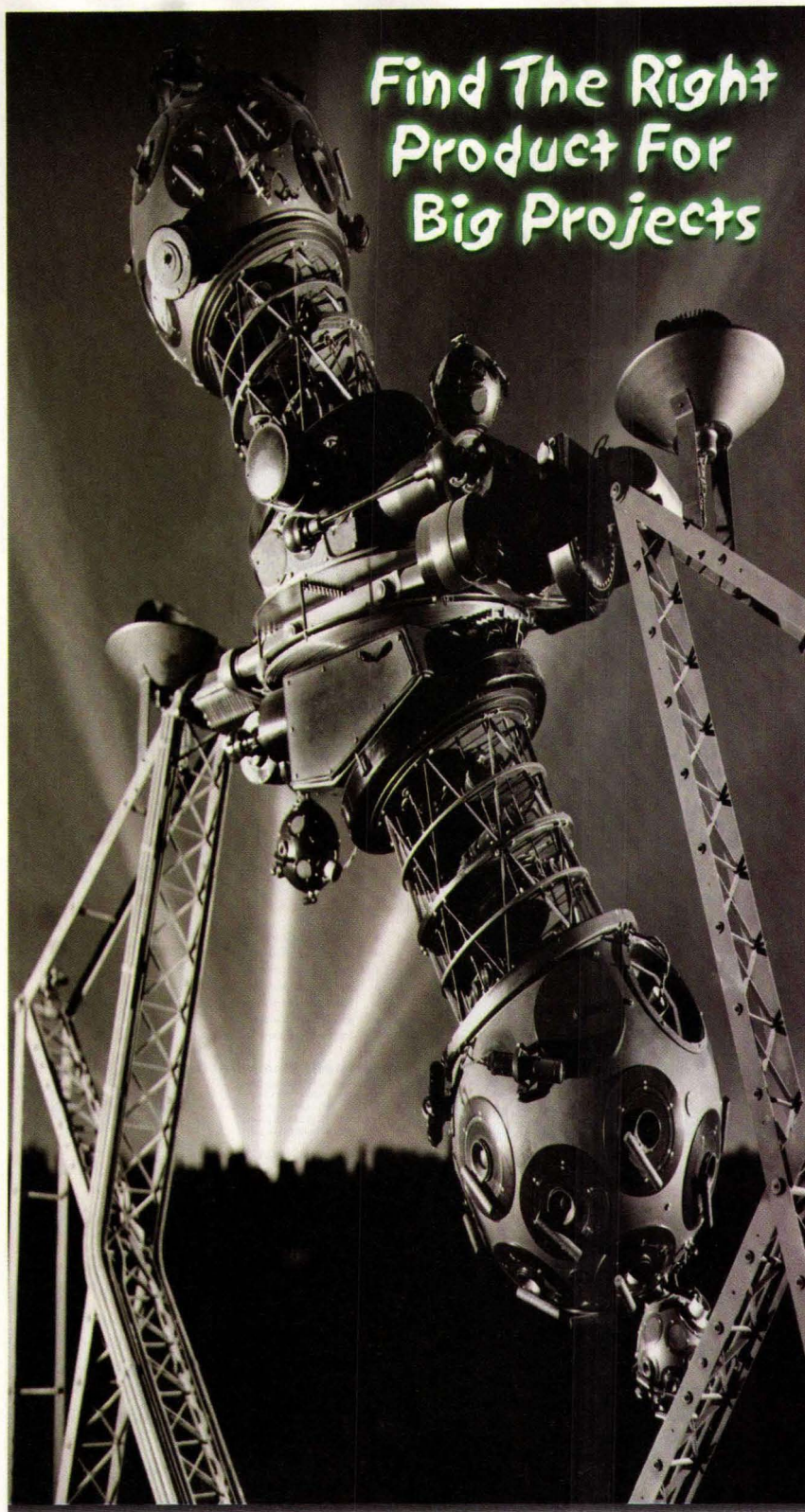
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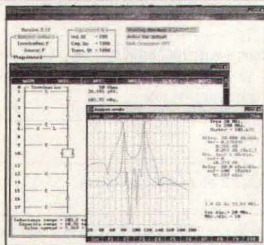
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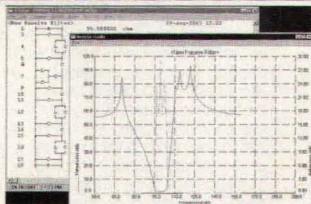
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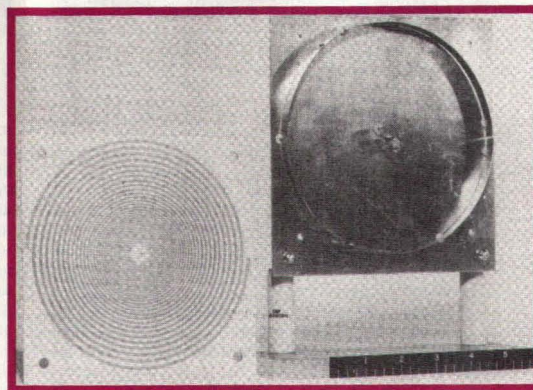


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← **looking back**



MORE THAN 32 YEARS AGO, researchers at the US Army Electronics Command (Belmar, NJ) pursuing low-voltage traveling-wave tubes (TWTs) revealed the feasibility model of a printed-circuit TWT with two spiral circuits enclosing an emitter-collector structure to form a vacuum.

→ **next month**

Microwaves & RF August Editorial Preview Issue Theme: Wireless Applications

News

August interrupts the "dog days" of summer with a special report on Broadband Technologies. As the general public increases its appetite for instant Internet access and the ability to download large files or view streaming video, the RF/microwave world must cope with methods of providing broader bandwidths and more efficient use of available spectrum. This report will examine the current push in wireless-local-area-network (WLAN) standards for higher-data-rate performance (to 100 Mb/s and beyond) as well as the growing number of companies pursuing broadband solutions for wireless voice, data, and video using ultra-wideband (UWB) techniques.

Design Features

August continues one of the most ambitious multipart projects ever to appear in this magazine: an eight-part design-feature collection on amplifier design. The author, Dr. Joseph White of JFW Technology, promises that all who read the entire series will be ready and able to design their own microwave ampli-

fier. Additional articles in August will support the wireless broadband theme with a report in generating UWB arbitrary waveforms by means of optical spectrum sculpting, details on the next generation of logarithmic amplifiers for wide-dynamic-range commercial and military receivers, and a study on how random noise contributes to timing jitter in high-speed communications systems.

Product Technology

August unveils the latest technology in flexible, multilayer printed-circuit-board (PCB) materials and bonding films. These low-dielectric-constant substrates feature uniform characteristics with time and temperature and provide the foundation for the next generation of compact, three-dimensional RF and microwave circuits. The August issue will also feature some of the latest products based on microelectromechanical-systems (MEMS) technology as well as a line of high-performance synthesizers suitable for commercial wireless and broadband military wireless applications.

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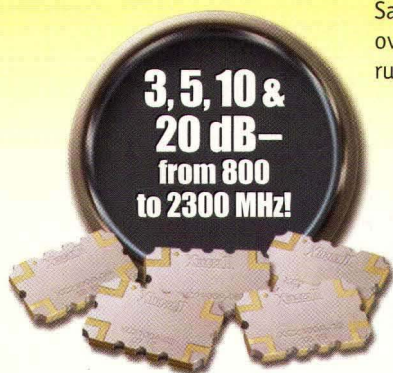
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